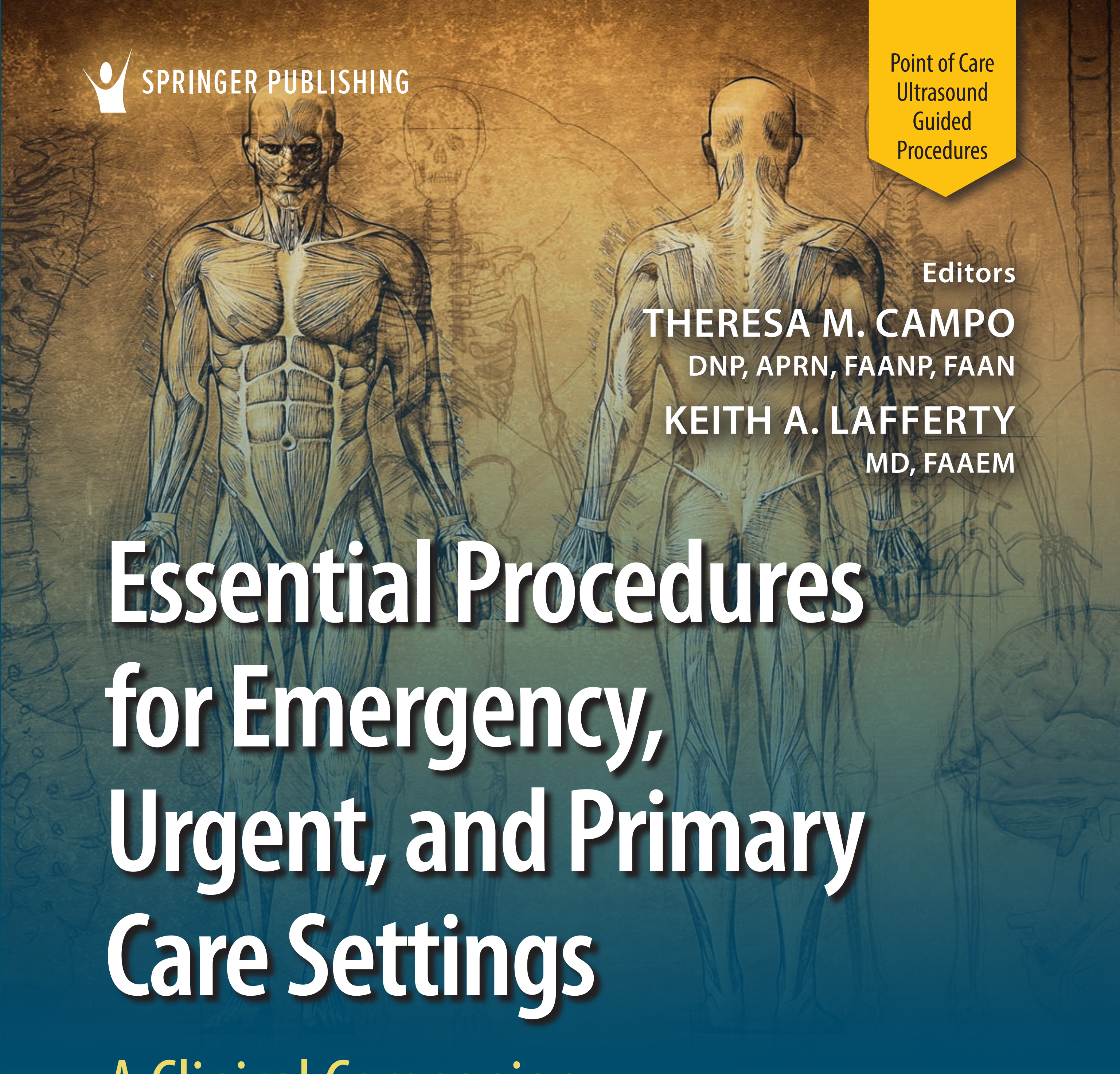

SPRINGER PUBLISHING

Point of Care
Ultrasound
Guided
Procedures

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DNP, APRN, FAANP, FAAN
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Essential Procedures for Emergency, Urgent, and Primary Care Settings

A Clinical Companion

Third Edition

Associate Editors
THOMAS G. COSTANTINO, JR., MD, FAAEM
JACOB W. UFBERG, MD
JENNIFER WILBECK, DNP, APRN, FAANP, FAAN

This book is composed in a manner that will help busy clinicians at the bedside. Those writing are active clinicians in busy, high acuity EDs who understand the value of quickly getting to the point when it comes to procedures in the practice settings this book is targeted for. A definite strength is the emphasis on ultrasound and procedures guided by ultrasound. My compliments to the editorial and writing team for "getting" what the frontline clinician needs in a procedure book.

Robert McNamara, MD, FAAEM
Professor and Chair, Emergency Medicine
Chief Medical Officer, Temple University Physicians

The editors have assembled a group of emergency care providers to offer the newest trends in procedures for those working in emergent, urgent, and ambulatory care settings. Each chapter provides a step-by-step procedural guide which is informative and concise. This is the perfect resource for the student or novice advanced practice provider who is looking for a real hands-on approach to procedures.

K. Sue Hoyt, PhD, RN, FNP-BC, CEN, FAEN, FAAN
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As a physician assistant in a busy emergency department and as a member of a trauma service in a level 2 trauma center, being proficient in procedures is critical. Whether it is in the ED, the trauma bay, or the ICU, if a procedure is needed it is often needed right away. It is imperative to be proficient and efficient to give patients the care they need and deserve. **Essential Procedures for Emergency, Urgent, and Primary Care Settings** *is a great resource to turn to for the most common procedures I perform on a regular basis.*

Seth Lauterbach MPAS, PA-C, CAQ-EM, SEMPA member

Essential Procedures for Emergency, Urgent, and Primary Care Settings

Theresa M. Campo, DNP, APRN, FAANP, FAAN, is chair of the Department of Emergency Medical Services (EMS) and the director of the Emergency Nurse Practitioner Track as well as associate clinical professor at Drexel University. Clinically, she is board certified as a family nurse practitioner and emergency nurse practitioner, and works part-time as a nurse practitioner in southern New Jersey.

Dr. Campo received her Doctor of Nursing Practice from Case Western Reserve University in Cleveland, Ohio. She earned her Master of Science in Nursing, Family Nurse Practitioner, from Widener University in Chester, Pennsylvania. Theresa has over 30 years of experience in emergency medicine, including prehospital, emergency department/quick care, and trauma. Dr. Campo is a founding board member of the American Academy of Emergency Nurse Practitioners, a national organization. She is a national and international lecturer on emergency and urgent care topics. Dr. Campo is the author of *Medical Imaging for the Health Care Provider: Practical Radiograph Interpretation* and has authored several book chapters and peer-reviewed articles.

Dr. Campo was inducted as a fellow of the American Association of Nurse Practitioners (AANP) in 2015 and Fellow of the American Academy of Nursing in 2017. She has received the alumni award for excellence from Case Western Reserve University and the state award of excellence from AANP.

Keith A. Lafferty, MD, FAAEM, received his BA in biology cum laude from Holy Family University in 1989 and his MD from the Medical College of Pennsylvania in 1994. At the completion of his training, his colleagues bestowed him with the “Senior Resident Teaching” award. Following his residency in emergency medicine and a faculty fellowship in critical care, he spent 10 years in full-time academia as a medical student director and a critical care director. Dr. Lafferty currently is the codirector of emergency medicine at Gulf Coast Medical Center, director of fire-based EMS in Fort Myers, Florida, adjunct assistant professor of emergency medicine at Temple University, board member of the Holy Family University Pre-Medical Committee, and board member of the Holy Family University President’s Advisory Committee. As a physician, Dr. Lafferty specializes in emergency medicine and practices in both Philadelphia and Fort Myers, Florida. As an author, he has written numerous chapters and manuscripts, mostly having to do with critical care procedures of emergency medicine, with an emphasis on advanced airway management. He has presented many of his research papers at the local and national levels. Because of his training, practice, and teaching in both emergency and critical care medicine, he passionately advocates the hybridization of these specialties in caring for the sickest of patients.

Dr. Lafferty has traveled to Haiti participating in mission expeditions after the devastating earthquake and continues to work with and educate Haitian physicians. The continuing evolution of bedside sonography has no doubt lent itself to bringing diagnostic and procedural accuracy to the most remote and vulnerable areas. Those experiences are reminiscent of his own humble beginnings growing up with his mother and sister in Philadelphia housing projects. Stemming from this, he also serves as chair of the board for both a local housing authority and a nonprofit benefiting such people. Providing medical care for the most indigent and teaching evidence-based medicine are the essence of his dedication to excellence in medicine.

Thomas G. Costantino, Jr., MD, FAAEM, received his BS in anthropology–zoology from the University of Michigan, graduating magna cum laude. He received his MD from the University of Michigan as well. He completed his emergency medicine residency at the Medical College of Pennsylvania and stayed to become their first emergency ultrasound fellow. He has worked at Drexel University College of Medicine and is currently a professor of emergency medicine at Temple University School of Medicine where he is the director of the Point-of-Care Ultrasound Fellowship in Emergency Medicine. Dr. Costantino has had the privilege of receiving several awards for excellence in teaching as well as serving in different leadership positions in different national medical organizations and peer-reviewed journals. He has published numerous scholarly articles relating to the field of emergency point-of-care ultrasound. He would like to extend a special thanks to Katie for her video and photo editing assistance.

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At every one of my encounters with patients, I know my actions are guided by the thoughts, principles, and passion of my mentors, Dr. Lynda Micikas, Dr. Robert McNamara, Dr. David Wagner, and Dr. Michael Williams. It is not only an honor to have been trained by the "best of the best," but even more so, to be a disciple of these pioneers and their relentless desire for perfection. I only hope the students I am privileged to teach are able to sense the illumination passed down to me, in order that they may also attempt to make this greatest of arts into the greatest of sciences. I am most grateful to the faculty and residents that comprise Temple University Department of Emergency Medicine. This monograph is enriched with the excellence, precision, and detail that only can come from a place of fostering evidence-based practice such as Temple University. Special thanks to Dr. Jacob Ufberg and Dr. Tom Costantino for not only being associate editors but more so for coordinating this enormous undertaking with the precision that represents only the best of training institutions. The time, commitment, and dedication spent editing this manuscript are small in comparison to the sacrifice given by my beautiful family. Cathy, you are my love and my soulmate . I am truly a better person because of you, and I love you more every day. This text would not have come to fruition without your continued and relentless encouragement, support, and unselfishness. Karli, Koko, and Kory: Mom and Dad realize and truly appreciate the sacrifices you've made, especially while we worked on this third edition. "To win the respect of intelligent people and the affection of children . . . to know even one life has breathed easier because you have lived."—Ralph Waldo Emerson. This is the true meaning of success. If you love what you do, it is not work! Daddy loves you so much and grows more proud of you every day. Always remember to equate success with the summation of one's virtuous acts.

Keith A. Lafferty

No journey is taken alone. The people and experiences are what shape the journey and make it educational. I am truly blessed to have mentors, Joyce Fitzpatrick, Margaret Fitzgerald, Elda Ramirez, Sue Hoyt, Dian Evans, and Jennifer Wilbeck, who have supported me and motivated me. This book would not be possible without the hard work and dedication of all the contributing authors, associate editors, and Springer Publishing. Margaret Zuccarini, you believed in a dream I had of producing a procedural book that would complement practice. Drs. Thomas Costantino, Jacob Ufberg, and Jennifer Wilbeck—thank you for bringing this book to life with consistency, accuracy, and expertise. I am grateful for the interprofessional approach of this book with authors from all disciplines coming together for this project. I have always said that we work together providing incredible care to our patients and we should learn and grow together. Working together accomplishes amazing things!

I would not be the person I am today without my father, Anthony Palmerio, and my husband, Jonathan Campo. Your unconditional love and support are amazing and I thank you from my heart and soul and dedicate this book to you both.

Theresa M. Campo

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Foreword

Having had the pleasure of being Dr. Lafferty's program director and serving as chair for a number of the authors, it is no surprise that this book is composed in a manner that will help busy clinicians at the bedside. Those writing are active clinicians in busy, high-acuity EDs who understand the value of quickly getting to the point when it comes to procedures in the practice settings for which this book is targeted. While other procedure books occupy a definite place for those who want a comprehensive review of the material, this work cuts to the chase while providing key references for further learning. A definite strength is the emphasis on ultrasound and procedures guided by ultrasound. The video links are an extra bonus on top of the clear descriptions and images. My compliments to the editorial and writing team for "getting" what the frontline clinician needs in a procedure book.

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Foreword

Essential Procedures for Emergency, Urgent, and Primary Care Settings: A Clinical Companion, Third Edition, is a unique book of procedures for use in emergency, urgent, and primary care settings. This distinctive book provides up-to-date information on "how to" perform procedures commonly done in these settings. This book will assist many different providers (e.g., physicians, nurse practitioners, physician assistants, advanced practice provider students) in their clinical settings.

Why should you purchase this book? Because it is concise, in-depth, and easy to keep with you in your clinical setting! This user-friendly, easy to understand, procedurally focused resource offers the necessary background information, illustrations, and step-by-step instructions for providing the safe and efficient treatment to patients in these care settings to not only the novice but to experts in emergent and urgent care.

Coeditors Theresa M. Campo and Keith A. Lafferty offer a wealth of information and knowledge combined with the expertise of Springer Publishing. In this edition, Associate Editors Thomas Costantino, Jacob Ufberg, and Jennifer Wilbeck, and contributing authors in every updated/revised chapter represent a variety of provider roles, making this a truly interprofessional endeavor. I know you will want to add this book not only to your medical library collection (Dooley Award) but more so in your clinical setting.

This is the third edition of this book. In addition to the ultrasound and videos, *Essential Procedures for the Emergency, Urgent, and Primary Care Settings* has also added more procedures, point-of-care ultrasound (POCUS) integrated throughout the entire book. There are expanded photo illustrations and videos. Additionally, there is also a chapter on interprofessional approach to procedures. As practice evolves, new knowledge is acquired, and procedures may change. In the meantime, I know you will enjoy utilizing *Essential Procedures for Emergency, Urgent, and Primary Care Settings, Third Edition.*

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Preface

INTRODUCTION

Welcome to the most current and heavily enriched, ultrasound-guided procedure book for advanced clinicians in emergency, urgent, and office settings. The intention of this book is to aid students and professional providers alike (nurse practitioners, physician assistants, physicians) in performing common and not so common procedures in these clinical settings. It is meant to be an expansive clinical companion that is easy to understand and follow while providing pertinent anatomy and physiology at a depth that helps the professional caregiver to comprehensively understand the procedure, not simply memorize sequential steps.

CLINICAL EXPERTS

This book has been prepared by clinical experts with numerous years of experience in both the academic and clinical arenas of their respective fields. Utilizing the most up-to-date literature as well as experience-based pearls of practice, we have organized this book to be user-friendly and broad-based. As busy clinicians, we all understand time constraints and the need for a well-organized and simplified procedural book. Numerous illustrations, photos, sketches, and videos are included to highlight and further explain many complex bedside procedures.

NEW TO THE THIRD EDITION

Recognizing the growing and robust use of point-of-care ultrasound (POCUS) to enhance the accuracy of numerous bedside procedures and diagnostics, this book is heavily enriched with POCUS content, which can be used to improve our ability to perform many procedures safely and accurately. There are two chapters dedicated to sonography that describe in detail the intricacies of this imaging modality. The coeditors and associate editors believe that true learning comes from a clear understanding of a subject at the most fundamental level. Grounded in fundamental sonography principles, these chapters provide readers with a clear understanding of ultrasound guidance, when applicable, which can be followed with confidence and ease. Also, the book has been expanded greatly to include 17 new chapters of more advanced procedures, with added depth of content and updated information to previous chapters. The book embraces interprofessional collaboration, which is evidenced by the contributing authors who are nurse practitioners, physician assistants, and physicians.

ORGANIZATION

The book is divided into 16 units covering the spectrum of simple, common, complex, and less common procedures performed by clinicians in emergency, urgent, and office settings. This collection of thoroughly described procedures is intended for use as a clinical companion and is an easy-to-use reference when performing such techniques. Current evidence-based literature has been utilized during the writing of this manuscript. For ease of reading, all resources are noted at the end of each chapter.

Chapters are organized in a format describing the background of the procedure, including the anatomy and pertinent pathophysiology of particular conditions requiring the procedure. Along with the actual procedures, additional treatments and considerations for care are outlined in each chapter. It is the intent of the authors to purposely describe in some detail the disease process for a better understanding of the indication and performance of the procedure. Videos have been prepared by the authors to support the understanding and accuracy of a procedure when performed in a clinical setting. The link to the videos is found in the text (springerpub.com/campo).

CLINICAL APPLICATION

Didactic learning and hands-on experience are required for safe skill acquisition before performing any procedure. To support clinicians in their learning, this book includes, when available, evidence-based best practices for procedures. A common theme of the editors, associate editors, and authors that underscores this manuscript is that POCUS is a most dynamic and growing field that has significantly improved, and will continue to improve, our ability to perform many procedures safely and accurately. Clinicians should always work within the scope of practice designated by their regulating agencies in their respective states and institutions. The editors, associate editors, authors, and contributors are not responsible for any actions resulting from the use of this text.

Theresa M. Campo and Keith A. Lafferty

Thomas Costantino, Jacob Ufberg, and Jennifer Wilbeck

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The editors and associate editors most humbly and graciously express sincere thanks to all of the patients for whom we have been privileged to care and who have placed their trust in our hands. Without you, this endeavor would not have been possible.

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UNIT

I

Introduction

CHAPTER

1

The Basics of Patient Procedures: Standard Precautions, Infection Control, Patient Preparation, and Education

Leigh Anne Pickup

Performing procedures not only requires technical expertise, but, to ensure a successful encounter, consideration must also be given to standard precautions, infection control, patient preparation, and patient education.

In the age of resistance, it is challenging to effectively treat infections. Consistent use of standard precautions is the best defense against spread of infections, either community or hospital acquired. Infection-control methods, including the use of standard precautions, are key to minimizing the spread of infection to healthcare workers, patients, and family members. Proper patient preparation and education also decrease infection. Routine implementation of these strategies increases a patient's level of satisfaction with the healthcare system and their understanding of the injury and/or disease process.

This book illustrates how to effectively prepare for each procedure in a confident, organized, and time-efficient manner. It also covers important educational points to share with patients to ensure a rapid and complete recovery.

STANDARD PRECAUTIONS

Standard precautions, previously termed *universal precautions*, have been practiced since 1983 when the Centers for Disease Control and Prevention (CDC) published guidelines for use by all healthcare workers to protect themselves from blood and bodily fluids that were potentially contaminated with blood-borne pathogens such as HIV or hepatitis B. Universal precautions were defined as "An approach to infection control in which all human blood, tissue, and certain fluids are treated as if known to be infectious for human immunodeficiency virus (HIV), hepatitis B virus (HBV), and other blood-borne pathogens" (Occupational Safety & Health Administration [OSHA], n.d.).

The term *standard precautions* was coined in 1996 by the CDC in an effort to broaden the focus of prevention. Rather than applying to only visible blood and bodily fluids, standard precautions also apply to nonvisible semen, vaginal fluids, tissue, and other fluids (such as amniotic, cerebrospinal, pleural, and peritoneal). In addition, the new guidelines introduced three transmission-based precautions: airborne, droplet, and contact. Standard precautions represent the minimum infection-prevention practices and should be followed at all times, for all patients, in all settings, regardless of disease or presumed infection status.

Implementation of standard precautions includes using barriers to protect the healthcare worker from contamination. Examples of these protective barriers include gloves, masks, goggles, and gowns. Additional precautions must be taken to protect healthcare workers from needle puncture by using needleless systems and needle-free products, and the use of vacutainers when possible. The required degree of protection depends on the potential threat to the healthcare worker for exposure.

Gloves should be worn whenever the potential for contact with blood or bodily fluids arises. Gloves should also be worn if handling contaminated items such as sheets, absorbent pads, bedside tables, and equipment. Gloves should be changed if their integrity is compromised (ripped, punctured, or torn) and if grossly contaminated. Handwashing should always be performed before and after wearing gloves.

Masks, protective eyewear, and gowns should be used during any patient contact or procedure when the risk of contact with fluids and/or tissue is present. These barrier items are best worn if splashing of the fluid is a potential threat; for example, droplets of blood or fluids, mucous membrane droplets (sneezing, coughing, etc.), or splashing of blood or bodily fluids during a procedure (active bleeding from a vein or artery, fluid under extreme pressure such as the contents of an abscess). Protective gear can also protect the patient, especially the immunocompromised, from the clinician and assistants.

INFECTION CONTROL

Infection-control procedures are important in protecting both the healthcare clinician and the patient. Basic handwashing is the simplest means to prevent transmission of disease. Handwashing before and after any patient contact, even if gloves were worn, should be a part of everyday practice.

When hands are not visibly dirty, alcohol-based hand sanitizers are the preferred method used for cleansing. Hand hygiene with alcohol-based hand sanitizer should take approximately 20 seconds and cover all surfaces of the hand and fingers until both hands feel dry. Research has proven that alcohol-based hand sanitizers are the most effective products for reducing the number of germs on the hands of healthcare clinicians (CDC, 2007). Antiseptic soaps are the next most effective. Nonantimicrobial soaps are the least effective. Soap and water are recommended for cleaning when hands are visibly dirty, there has been possible exposure to *Clostridium difficile* or norovirus, before eating, and after using the restroom. To be effective, handwashing with soap and water should be done for a minimum of 15 to 20 seconds, covering all surfaces of the hands and fingers.

Good handwashing techniques, in conjunction with standard precautions, are to be implemented before and after all procedures presented in this book. Gloves, gowns, and protective eyewear should be worn whenever there is potential exposure to blood or bodily fluids. The CDC recommends that personal protective equipment (PPE) be donned in the following sequence: (a) gown, (b) mask or respirator, (c) goggles or face shield, and (d) gloves. Use of needleless or needle-free products is encouraged but depends on what equipment is provided in various facilities.

PATIENT PREPARATION

Preparing the patient, mentally and physically, for a procedure is as important as performing the procedure. All procedures, whether seemingly basic, advanced, or emergent, are invasive to the patient and should be discussed with the patient in as much detail as the situation allows. Discussions should include the potential risks and benefits of performing the procedure versus not performing the procedure. Care should be taken to discuss the various techniques available for the particular situation at hand (i.e., suture closure versus skin adhesive) and the risks and benefits of each method. Lastly, follow-up care and expectations should be clearly explored with the patient, confirming understanding.

Continued reassurance should be given not only to the patient but also to the family member(s). Communicating confidence while offering a clear plan and expectations support improved patient satisfaction and procedure outcome. When speaking to a patient, keep your voice low and slow, pause at regular intervals to provide the opportunity for questions, and always speak directly to the patient, even if the patient is a young child. On completion of the discussion, allow ample time for further questions and explanations. If possible, do not move forward with the procedure until all questions and concerns have been addressed. Confidence and trust go a long way. Consent must be obtained before initiating the procedure.

Every effort should be made to make the patient and family member comfortable prior to and during the procedure. Place the patient in a comfortable position, especially if the procedure will be lengthy. Having a family member sit in a secure chair on the opposite side of the stretcher or examination table ensures that this person is not only physically out of the way, but also safe in the case of nausea or syncope resulting from visualizing the procedure. Any assistant should also stand on the opposite side to provide help and also ensure the visitor remains safe during the procedure.

In this book, the required equipment is listed in the “Procedural Preparation” section of the chapters. All efforts to list what will be needed as well as alternative equipment have been made. Developing a checklist of equipment is helpful to ensure everything that is needed will be available at the bedside. Exiting to obtain necessary equipment during the procedure is time-consuming and may communicate disorganization and poor preparation to the patient and family.

Once the equipment is at the bedside and consent has been obtained, continued reassurance should be given to the patient and any family members present. Parents and family members should be allowed at the bedside when appropriate at the clinician’s discretion. Standard precautions should be strictly followed for all procedures. When performing the procedure, every effort should be made for the clinician to be in a comfortable position. Body mechanics are key for the clinician as well as the assistants. Some procedures can be lengthy and stress the neck and back. Employing simple measures to ensure proper body mechanics and comfortable positioning (e.g., sitting in a chair, adjusting the height of the stretcher/examination table, having the patient positioned close to you to avoid reaching, and maintaining proper lighting) is imperative.

PATIENT EDUCATION

Taking time to properly educate the patient about follow-up, medications, wound care, and pertinent procedure-related information can save time and frustration for the patient and clinician. Providing verbal instructions followed by written instructions is ideal. Reviewing the procedure that was performed, proper care and management at home, and follow-up expectations are the key components of any discharge instructions. Always allow time for questions and further discussion to ensure the patient and family members have a good understanding of what is required. Once the information has been presented to the patient and family members, simply ask the patient and/or family member to repeat what you have discussed to ensure comprehension.

Patient anxiety levels, medications, and the trauma of experiencing a procedure can impact what information the patient actually absorbs. Providing written instructions reinforces patient education and guides follow-up. Written instructions can be obtained through software companies specializing in patient instructions or via the internet. Fully review the instructions for accuracy before distributing them to patients. Instructions that are consistently updated based on current evidence-based practice are best.

Documentation of verbal and written instruction is extremely important. Be sure to document what was discussed and provided to the patient, exact details for follow-up (i.e., primary care physician [PCP], ED, urgent care, or specialist), and whether the patient and/or family member verbalized understanding of the instructions as well as specific questions that were addressed.

SUMMARY

Prior to beginning any procedure, review the particular procedure in this book (including the video when provided), and then review it once again in your head. Plan how to proceed and envision the parameters of the procedures before you begin. Take a deep breath. Doing this will help to ensure that you place yourself in a comfortable position and state of mind, which will sustain you throughout the procedure. There is nothing worse than bending over too far or standing during a time-consuming procedure and suffering a resultant stiff back or sore legs. When possible, sit on an adjustable chair or stool while performing a procedure. Adjustments can be made during the procedure, if necessary, to avoid bending over for prolonged periods of time, causing posture strain that can lead to clinician discomfort, pain, sloppiness, and inferior results. Be sure to take care of yourself before taking care of others.

Implementation of standard precautions, which encompass infection control, patient preparation, and education, are the key elements to any procedure performed in the emergency, urgent, or primary care setting. Clinicians need to deliver high-quality, efficient care while keeping the patient comfortable and calm. Achieving these goals requires taking extra steps to prepare properly for the procedure, to educate the patient and their family, and to be compassionate during every patient encounter.

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CHAPTER

2

Consent, Documentation, and Reimbursement

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The documentation and legal aspects of medicine and nursing are often overlooked, yet they are very important. Obtaining the proper consent, becoming familiar with the ethics of best practices, documenting thoroughly and accurately, and being knowledgeable about reimbursement practices and legislation in American healthcare are all integral aspects of healthcare and performing procedures in any clinical setting. Having a basic understanding of these principles and how they impact practice and patients can aid clinicians in making good, sound, and ethical decisions for the patient, healthcare team, and self.

CONSENT

Consent can be defined as giving verbal or written approval or permission to receive a given type of medical treatment or examination by a person with sufficient mental capacity and appropriate age or by a legal representative. *Informed consent* is the patient's right to be presented with sufficient information about a recommended procedure or treatment by the clinician or a representative for the purpose of enabling the patient to make an informed decision regarding their care. Patients or their representatives have the right to and should fully participate in the informed-consent process. In seeking informed consent, the clinician performing the procedure or treatment should explain what is being offered, and should include the following essential elements in the discussion:

- Diagnosis
- Name of the procedure or treatment
- Person performing the procedure or treatment
- Purpose of the procedure or treatment
- What the procedure or treatment entails
- The risks, benefits, and expected outcomes of the procedure or treatment
- Alternatives to the procedure or treatment
- Risks and expected outcomes of not receiving the procedure or treatment
- The prognosis surrounding the diagnosis and the procedure or treatment

The clinician should assess the patient's ability to understand relevant medical information and implications of procedure or treatment alternatives to make an independent, voluntary decision prior to obtaining informed consent.

Informed consent is necessary for any patient who undergoes any invasive procedure or medical treatment, and can be divided into *expressed consent* and *implied consent*. All forms of consent have become more important as a result of the increasing amount of litigation in healthcare. *Expressed consent* occurs when the patient consents to treatment or procedures through direct agreement—either written or verbal. *Written consent* requirements are stipulated by individual hospitals and mandated by The Joint Commission. Written consent is utilized as a method of proof that the information was explained to the patient or representative and is valid indefinitely, pending no change in the patient's condition or new information impacting the intervention during the intervening period. If consent is obtained verbally, it should be clearly documented in the patient's medical record as part of the procedure or treatment. *Implied consent* can be obtained in an emergency situation when there is a risk to the patient's life or if serious impairment or permanent injury to life or limb can occur with no intervention. Examples include cardiac arrest, trauma, and significant fracture with neurovascular compromise. In the absence of a durable power of attorney, the closest available relative or legal guardian may authorize necessary and reasonable care when a patient is incapable of giving consent.

Consent for minors must be obtained from either a parent, legal guardian, or from the minors themselves in situations in which assent is necessary or they are emancipated. Assent occurs when the child is provided with age-appropriate information about the procedure or treatment in language that they can understand and agrees to the procedure in addition to permission from a parent or legal guardian. An emancipated minor is legally free of parental control and is treated as an adult in consent cases as allowed and designated by state laws. Examples of emancipation include designation as a mature minor, marriage, or being parents themselves. State laws should be referenced for further guidance. A family representative may also provide consent for treatment as long as there is written documentation from the minor's parent or legal guardian. Regardless of the status of the patient or representative, the procedure should always be explained in terms that the patient can understand.

Anyone who is mentally competent, able to make their own medical decisions, autonomous, and not experiencing central nervous system dysfunction (i.e., alcohol, drugs, ischemia, or metabolic derangement) has the right to refuse a procedure or treatment, even if the clinician feels it is necessary. In cases of refusal, patients should be made aware of any risks of not having the procedure or treatment. Always refer to state law and institutional policies with regard to consent, as these may differ from state to state and between institutions. Prior to beginning any procedure discussed in this book, remember, as stated above, to discuss the diagnosis, procedure, potential complications, risks, benefits, intended effects, and alternatives with the patient or representative. In addition, discuss the importance of follow-up and the expected time frame for reevaluation, if any. Appropriate consent for each situation involving procedures or treatments should always be obtained, congruent with state laws, institutional policies, and ethical obligations of the profession to the public.

LEGAL AND ETHICAL CONSIDERATIONS

With regard to healthcare delivery, malpractice is a concern for clinicians, especially when performing procedures. *Malpractice* is defined as deviation from the standard of practice through an act or omission that results in injury or complication to the patient. Providers must be cognizant of the most current guidelines and standards of practice for each procedure that they perform. Care must be taken to "first do no harm," which can be accomplished by regular review of the current literature, regulations, and practice guidelines. Clinicians must also be cognizant of applicable state rules and regulations in regard to performing procedures. State laws can vary widely from no regulation to specific protocol documentation and the need to request permission from the state to perform specific procedures. Laws also vary among physicians, nurse practitioners, physician assistants, and other providers.

Ethical issues can potentially lead to legal ramifications. Cultural and religious beliefs can impact a patient's plan of care and place the clinician in difficult situations. What is standard care for a majority of the patient population may not be acceptable to a particular patient based on one or several of these factors. Receiving blood products or certain medications and treatments may be thought to be detrimental or unacceptable by certain religious, cultural, or ethnic groups. When clinicians face these situations, they should respect the wishes of the patient or representative, but also discuss risks, benefits, and alternatives thoroughly utilizing the informed-consent process. The clinician may also consult with the ethics committee of the institution for guidance when the acceptable alternatives to the procedure for the patient or representative would be detrimental in nature. Respecting the patient's or the representative's beliefs and practices is a critical component of patient- and family-centered care that can prove to be difficult in these situations. Regardless of competing priorities, always use a collaborative approach with the patient, family, community, and healthcare team.

Healthcare liability and resulting litigation are great concerns for every clinician. Proper training in procedural techniques, improving the consent process, malpractice reform, tort reform, and capitation are methods utilized to improve the outcomes as well as to regulate legal ramifications in healthcare. Providers should be knowledgeable regarding the scope of practice, national and state laws that govern their practice, and reimbursement of procedures as they may vary widely. Documentation of procedures performed in the health record has become one of the most important tools in defending clinicians from lawsuits and litigation. Proper and thorough documentation is essential not only in the setting of litigation, but also for obtaining reimbursement from third-party payers for services rendered.

DOCUMENTATION AND REIMBURSEMENT

Reimbursement is an essential component of practice in the ongoing economic climate and in healthcare is defined as the payment for healthcare services (Castro & Layman, 2006). As institutions attempt to control soaring healthcare costs, it is important for the clinicians to document accurately and completely in order to maximize reimbursement. Signed into law in 2010, the Affordable Care Act (ACA) encouraged the utilization of the electronic health record (EHR) through an incentive program. As a result, patients and clinicians are able to better utilize clinical information to improve healthcare quality, reduce costs, and increase access and analysis of stored health information. The ACA also phased in requirements of individuals to maintain some form of healthcare coverage, further encouraging institutions and clinicians to become more knowledgeable about procedures and their reimbursement.

Coding of disorders and causes of death can be traced to the 17th century. The *International Classification of Diseases* (ICD) was started in the 1900s in France and originates from the international classification of causes of death. It listed 179 groups of causes of death and an abridged classification of 35 groups. In 1946, responsibility for the ICD was transferred to the World Health Organization, which continually reviews and revises this classification system, which is currently in its 11th edition, also known as *ICD-11*.

In order to determine reimbursement, healthcare providers should research what the Centers for Medicare & Medicaid Services (CMS) and private insurance agencies have designated as reimbursable procedures, what technology assessment recommendations are required, and what the assigned Current Procedural Terminology (CPT) codes are for each procedure. Many EHRs are developed to capture all of the essential documentation elements necessary to obtain maximum reimbursement for services rendered, including procedures.

CPT codes use a universal system of numbers and descriptors that identify healthcare services that involve payment. These codes were designed and are updated yearly by the American Medical Association (AMA). The system assists in streamlining service reports and increases the accuracy of documentation, allowing for a more efficient means of communicating healthcare services provided. If a procedure does not have a code, it may not be reimbursable or is too new to have one designated to it. An example of this occurs with new technology. Coverage for new technology may be integrated directly into the diagnosis coding for the patient condition and not as a separate procedure.

The EHR must reflect pertinent health information, including history of present illness (HPI), physical examination findings, overall assessment with diagnoses, and plan of care. Collaborative patient- and family-centered care, including communication paired with thorough documentation, can promote realistic expectations for the patient and help decrease the risk of malpractice allegations. Documentation needs to be complete and legible for the purpose of claims review, quality improvement, peer review, and faster reimbursement processing.

Evaluation and management (E&M) guidelines first published by the CMS in 1995, and then revised in 1997, are still utilized in documentation and billing practices today. There are three key components in this process: the history, physical examination, and medical decision-making (MDM).

The history is the subjective narrative that provides information on the current problem and the symptoms leading to the encounter. It is composed of the following:

- The chief complaint
- HPI
- Review of systems (ROS)
- Past medical/family/social history

The E&M guidelines recognize that the history varies in complexity and detail. There are eight components of an HPI:

- Location
- Quality
- Severity
- Duration
- Timing
- Context
- Modifying factors (relieving and aggravating)
- Associated signs and symptoms (CMS, 1997)

The documented history can be categorized as brief or extended and be further subdivided into four levels based on complexity and detail. These history levels are problem focused, expanded problem focused, detailed, and comprehensive histories. **TABLE 2.1** outlines the criteria for the four levels of history. Regardless of the level of history, all require a chief complaint and some form of an HPI.

The physical examination is the second component of E&M documentation and also has four levels of detail based on complexity. The four levels of the physical exam are problem focused, expanded problem focused, detailed, and comprehensive exams. The details for the physical examination must follow the revised criteria designated in the 1997 E&M guidelines, which provide more detailed guidance with bulleted lists of the elements for each organ system examination. A total of 14 organ systems with bulleted elements are identified in the 1997 guidelines. The number of systems and elements documented serves to determine the level of the physical exam. For example, two elements from nine systems must be addressed at minimum to comprise a comprehensive physical examination (American Academy of Professional Coders, 2012). Please see **TABLE 2.2**.

MDM is the most important of the three components. Four factors are used to determine the level of complexity in MDM. These levels of complexity are straightforward, low complexity, moderate complexity, and high complexity.

TABLE 2.1 Criteria Required for History Levels

Level of History	HPI Elements	ROS	Medical/Family/Social History
Problem focused	One to three	None	None
Expanded problem focused	Four HPI or status of three or more chronic conditions	One system	None
Detailed	Four HPI or status of three or more chronic conditions	Two to nine systems	Pertinent elements
Comprehensive	Four HPI or status of three or more chronic conditions	10 systems	Complete

HPI, history of present illness; ROS, review of systems.

TABLE 2.2 Physical Examination-Level Criteria

Level of Physical Examination	Number of Systems and Bullets	Total Number of Bullets Required
Problem focused	1–5 bullets from 1 *or* more organ systems	1–5
Expanded focused	At least 6 from any organ systems	Minimum of 6
Detailed	At least 2 bullets from 6 organ systems *or* 12 bullets from 2 or more organ systems	Minimum of 12
Comprehensive	2 bullets for each of 9 organ systems	Minimum of 18 but 20 is better

The first determinant of MDM is risk. Risk is based on the number of diagnoses or management options along with the amount or complexity of data reviewed and the potential risk of complications, morbidity, and mortality. The highest number or likelihood of occurence of any of these three areas helps to determine the overall risk. This method has been found to be very subjective and CMS has developed a point system in order to audit health records accordingly. All health record audits conducted by CMS utilize this point system, and it is recommended for all Medicare carriers, though it is not part of the E&M guidelines.

The point system makes risk and MDM more objective by assigning a numerical scale to describe each problem, then points are utilized to determine how much information the healthcare practitioner needs to process in order to make a decision for the patient situation at hand. As an example, for a self-limiting or minor problem (up to two), a clinician would receive one point for MDM for this encounter. For a new high-risk problem with the need for additional studies, four points for MDM would be used for this encounter. Data points are then added to each encounter and diagnosis. Data points are determined by the diagnostic studies that are either reviewed or ordered for the encounter. As an example, if a clinician reviews laboratory diagnostic results, one point would be given for MDM for this encounter. Likewise, if a clinician orders laboratory studies, one point for MDM would be given. However, a clinician cannot receive two points for reviewing current laboratory studies and ordering future laboratory studies. Only one point would be allowed for MDM in this circumstance. Lastly, management options that are recommended or ordered are determined. Problem, data, and risk level comprise the complexity of MDM. All three areas have points determined objectively, providing the clinician with guidance on MDM complexity on a case-by-case basis (**TABLE 2.3**).

Knowledge of the rules and laws that govern student documentation is also important for a teaching clinician to understand. In 2018, CMS updated a ruling that states that medical student documentation that is attested to by a teaching physician is allowed to serve as documentation of the encounter and can be submitted for E&M reimbursement for services rendered. Nurse practitioner and physician assistant students were not mentioned in this ruling; therefore, it has been interpreted that nurse practitioners and physician assistants must continue to provide full documentation of procedures or treatments, in addition to the documentation of their students, in order to receive reimbursement.

Clinicians should continue to work diligently to understand and master the complexity of the E&M guideline system with the intention of avoiding fraud. The combination of *ICD-11* and CPT codes determines what are billable medical services. It is the documentation, however, that must support the CPT code. If the documentation does not meet the required elements for billing, the healthcare practitioner can be charged with fraud and be subjected to inspection and potential prosecution by the Office of the Inspector General of the Department of Health and Human

TABLE 2.3 Summary of Medical Decision-Making

Complexity of Medical Decision-Making	Problem Points	Data Points (Diagnostics)	Risk Level
Straightforward	1	1	Minimal: One self-limited or minor problem
Low complexity	2	2	Low: Two self-limited or minor problems *or* one stable chronic *or* one acute stable condition
Moderate complexity	3	3 (complex, often invasive)	Moderate: One or more chronic illnesses with exacerbation; two or more stable chronic conditions; acute illness with systemic symptoms; *or* acute complicated injury
High complexity	4	4 (often invasive)	High: One or more chronic illnesses with exacerbation or progression; acute or chronic illness that poses a threat to life *or* body function; *or* abrupt change in neurological status

Services. The EHR is an efficient, time-reducing, and cost-containing tool for documenting patient encounters, which allows for more readily available medical information and increased ease of access, resulting in more thorough care of the patient and reduction in the duplication of services. In some EHR programs, E&M codes can be entered along with documentation so that the EHR program helps to ensure that the proper billable documentation has been achieved, but the clinician must still determine and document the MDM complexity. In the past, obtaining pertinent patient information would have been delayed or unobtainable, but there are now EHR programs that allow patient care information to be shared among clinicians within institutions and other sites with access to the same EHR and data. This increased access has helped with documentation and billing compliance.

As documentation provides the basis for coding and thus reimbursement, targeted documentation is often required to fully capture the complexity of the patient condition. Within emergency care, this is most commonly seen with billing of critical care time.

Critical care time coding is applicable when the following three conditions are satisfied:

- At least one vital organ system is acutely impaired.
- There is a high probability of imminent and life-threatening deterioration.
- The clinician intervenes in an attempt to prevent further deterioration of the patient’s condition.

Critical care time coding is appropriate when greater than 30 minutes is spent providing patient care in the previously noted conditions. The time does not need to be continuous, and may represent an additive (or cumulative) amount of time spent in direct patient care exclusive of separately billed procedures. Examples of activities supporting the critical care time requirement include the following:

- Time at a patient’s bedside
- Time reviewing tests or images
- Time discussing care with other clinicians
- Documenting the medical records
- Time spent with other decision-makers when patient is unable to make decisions

SUMMARY

Clear communication among healthcare providers, patients, representatives, and third-party reimbursers provides multiple opportunities for improved quality, data collection, continuity of care, and patient outcomes. Strategies to support best outcomes include obtaining the proper consent before performing any form of procedure or treatment; knowledge of legal, ethical, and liability concerns; and accurate documentation in accordance with guidelines to provide the foundation for competent and thorough care. Thorough and accurate documentation lead to better communication among clinicians and decreased liability, and results in accurate and maximal reimbursement.

All clinicians should have a basic understanding of how national and state laws, along with reimbursement, impact clinical practice and patient access to basic medical services. It is the ethical and legal obligation of every clinician to educate each patient and appropriately document the care that is provided in return for reimbursement. Clinicians should always take the time to listen and communicate with their patients in a manner that they understand, particularly regarding procedures. This will provide a basis for realistic expectations of the procedure and possible outcomes.

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CHAPTER

3

Interprofessional Approach to Performing Procedures

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INTERPROFESSIONAL COLLABORATION

Physicians, physician assistants (PA), and nurse practitioners (NP) have been practicing together to provide team-based care for many years. Although the roles of each differ in some respects, each clinician performs procedures following procedure-specific education and supervised experiences. Differences in the formal academic education, certification, and licensure among the three roles provide unique care-delivery opportunities in which the abilities and background of each clinician are valued. Research efforts led by the Institute of Medicine demonstrated that interprofessional education can improve knowledge, skills, and understanding of interprofessional practice. However, the relationship between interprofessional education and outcomes has not yet been clearly established (Cox, Cuff, Brandt, Reeves, & Zierler, 2016).

Interprofessional collaboration and practice are integral for achieving positive patient outcomes regardless of the practice setting. Depending on the practice setting, interprofessional teams may include providers, nurses, medical/nursing assistants, respiratory therapists, laboratory technologists, radiology technologists, clerical personnel, and social workers. Each person plays an integral part in patient care. Cohesive teamwork and collaboration with open communication have demonstrated improved patient outcomes, decreased length of stay, and improved patient and staff satisfaction with care provided (Epstein, 2014).

In addition to interprofessional education and clinical collaboration, understanding and respecting the similarities and differences in education, certification, licensure, and scope of practice for varied provider roles supports the delivery of efficient and safe patient care.

EDUCATION

Physician

Physician education consists of 4 years of undergraduate education, 4 years of medical school, and a residency program in the respective field of interest (emergency, family medicine, surgery, etc.). Depending on specialty, postgraduate fellowships may also be completed. Medical schools generally provide didactic courses in the first 1 to 2 years followed by integration of clinical rotations through various specialties. The length of residency depends on the specialty of interest. Residency programs prepare physicians through collaborative practice with experienced licensed attending physicians. During the residency, physicians track procedures completed under the supervision of the attending physician as part of the criteria for completing the residency. This log and documentation of procedures performed can be utilized for credentialing upon completion and hire of physicians into independent practice. Residency and fellowship programs are structured to align with guidelines set forth by the Accreditation Council for Graduate Medical Education (ACGME).

Physician Assistant

Following completion of an undergraduate college degree, PA education occurs at the master's degree or postgraduate educational level. The undergraduate degree is usually a science-based degree (i.e., biology, premed, etc.). If the undergraduate degree is not in the science field, then numerous science courses must be completed prior to beginning the PA program. The curriculum is based on the medical model and encompasses didactic and clinical education and training. Programs may have a focus of primary care, acute care, or both. Clinical rotations are a focus of the PA program, which may include but are not limited to medicine, surgery, pediatrics, orthopedics, women's health/obstetrics, geriatrics, and emergency medicine. The PA is poised to enter specialties upon graduation and also has the ability to move from one specialty to another if desired. Programs are accredited by the Accreditation Review Commission on Education for the Physician Assistant (National Commission on Certification of Physician Assistants [NCCPA], n.d.).

Nurse Practitioner

NP education follows completion of an undergraduate nursing degree, and consists at minimum training at the master's or post-master's level. The DNP represents the terminal degree. Education is based on the LACE model of licensure, accreditation, certification, and education within the APRN consensus model. In contrast to the broad PA educational model, academic preparation for NPs is targeted to a specific population (family/individual across the life span, adult–gerontology, pediatrics, neonates, women's health/gender-specific healthcare, and psych–mental health). Some academic programs may focus on acute care or primary care within the population. Education of NPs is overseen by the National Organization of Nurse Practitioners (NONPF) and accredited by the Commission on Collegiate Nursing Education (CCNE) or the American Association of Colleges of Nursing (AACN). Education beyond the population level is considered to be a specialty and is overseen by the primary specialty organization. Specific competencies aligned with specialty practices, such as emergency NPs, are met through graduate and postgraduate academic programs, postgraduate fellowships, or through experience working in the setting (AACN, n.d.-a, n.d.-b); NONPF, n.d.).

Continuing Education

All providers are required to obtain continuing education (CE) to maintain certification. Specific requirements are outlined by certification organizations, state boards, and facility credentialing specifications, but the goal remains to keep clinicians updated on current practices and evidence-based care. Participation in CE events is recognized by certificates of completion documenting the hours of attendance and may be provided through nursing or medical organizations accredited to provide the hourly credit for attendance.

CERTIFICATION

Physician

Physicians are not required to obtain board certification in order to be licensed. However, board certification may be necessary for credentialing by hospitals, outpatient facilities, or practices. The certification may be obtained from accredited organizations such as the American Board of Family Medicine (ABFM), American Board of Emergency Medicine (ABEM), American Board of Internal Medicine (ABIM), and others. Board certification may consist of written and oral testing of competency. Recertification may occur through CE credits, current license, clinical experience, and/or testing (ABEM, n.d.; ABFM, n.d.; ABIM, n.d.; American Board of Medical Specialties, n.d.).

Physician Assistant

Upon graduation from an accredited college or university, PAs are eligible to complete board certification consisting of an examination provided by the Physician Assistant National Certifying Examination (PANCE). Recertification is required every 10 years and consists of CE credit and an examination (NCCPA, n.d.).

Nurse Practitioner

NPs are eligible for board certification within the population focus upon graduation from an accredited NP program. For example, a family NP graduate is eligible to complete the family NP board-certification examination. Numerous board-certification examinations for each population foci are available. Certification boards include but are not limited to the American Academy of Nurse Practitioners Certification Board, American Nurses Credentialing Center, Pediatric Nursing

Certification Board, National Certification Corporation, and others. Recertification is every 5 years and consists of either CE credit with active clinical practice or examination.

LICENSING AND REGULATION

Physician

Licensure is required for all physicians to practice and is regulated by the state medical boards. Traditionally, reciprocity existed between some states but this practice has mostly been discontinued. There may be variations between the state requirements, but all states require proof of completion of the three steps of the United States Medical Licensing Examination (USMLE). States may require proof or verification of education, graduate training, exam scores, references, and hospital privileges.

Physician Assistant

PAs are required to be licensed in the state in which they practice. Requirements may include graduation from an accredited program, baccalaureate degree, and board certification. Renewing the PA license differs from state to state and requires either CE credit, NCCPA examination, or both (American Academy of Physician Assistants, n.d.).

Nurse Practitioner

State licensure differs from state to state. Requirements may include successful completion of a graduate-level accredited NP program and board certification. Regulation comes from individual state boards of nursing, supported by the National Council of State Boards of Nursing (NCSBN). The NCSBN provides a mechanism whereby "regulatory bodies act and counsel together on matters of common interest and concern affecting public health, safety and welfare, including the development of nursing licensure examinations" (NCSBN, n.d.). There is a nursing compact between some states allowing nurses to practice in states that are part of the compact without applying for licensure in those individual states.

SUMMARY

There are overlapping requirements for the roles of physician, PA, and NP in terms of education, certification, and licensure. However, there are also distinct differences that make each role unique. The education and training, experience, and practice setting allow individuals to gain strengths in certain procedures. Collaboration among clinicians and other team members is integral to achieving high-quality patient care, especially when procedures are performed. A firm understanding of procedural indications, contraindications, techniques, landmarking, and integration of ultrasound is necessary to prevent complications and negative patient outcomes.

Physicians, PAs, and NPs provide collaborative care not only to support patient outcomes, but to support each other in individual roles within a team-based care model. It is imperative that each clinician maintain current knowledge and skills through CE and clinical practice. Interprofessional approaches to education and practice have been demonstrated to support positive patient outcomes and lower complication rates. We must learn together, practice together, and—most of all—appreciate and respect what we bring to patient care together.

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UNIT II

Introduction to Sonography

CHAPTER 4

Introduction to Ultrasound and Knobology

James Murrett, Thomas Costantino, and Aubrey Rybyinski

INTRODUCTION

The field of ultrasound has grown rapidly to become an integral part of many clinical practices. Ultrasound has been established as a safe and effective form of imaging that has been used by clinicians for more than half a century to aid in diagnosis and guide procedures. The growth of point-of-care ultrasound (POCUS) and its application has exponentially increased over the last decade as more compact, higher quality, and less expensive equipment has become more available. Furthermore, there is a good deal of literature demonstrating its ability, in the trained hands of clinicians making real-time decisions, to significantly decrease morbidity and mortality, eliminate previous diagnostic delays, and increase procedural precision. Because of this, the technology is now ubiquitous in many acute care clinical settings. Sonography is a highly user-dependent technology, and as its clinical usage grows, there is a need to ensure education on proper use as well as limiting unnecessary imaging and its consequences. The use of this bedside tool in a focused manner will greatly enhance the ability to diagnose, resuscitate, monitor, guide, and treat acute medical conditions. Education in POCUS is currently an essential part of emergency medicine training programs and a growing part of acute and primary care programs. Comprehensive training guidelines are published to ensure proficiency in ultrasound education and are currently the ***standard of care in modern-day EDs. The days of indirectly ascertaining pathology via auscultation and palpation have now been augmented by real-time bedside imaging, thanks to mobile sonography.***

PRINCIPLES

The basic frequency unit in ultrasound is the hertz (Hz), which represents one cycle per second. *Ultrasound* is defined as a frequency above that which humans can hear, more than 20,000 Hertz (20,000 cycles per second) or, stated another way, 20 kilohertz (kHz). The frequency of diagnostic ultrasound is in the millions of hertz (MHz); hence, we cannot hear these sound waves. Ultrasound historically uses a quartz crystal or composite piezoelectric crystals, which generate a sound wave when an electric current is applied, causing them to change shape rapidly, thereby creating vibrations and hence sound waves that travel outwardly. Note, traditional crystal probes are relatively expensive and, because of inherent complexities, you have to have a different probe for different parts of the body as each probe uses one particular frequency.

Recently, the piezoelectric crystals have been replaced with miniature vibrating silicon-filled drums (which are molded to a semiconductor), which are less costly to manufacture. The thousands of silicon-filled drums wobble/change shape (analogous to crystals) and create the ultrasonic sound wave; they also receive them back as the drum/silicon chip is impregnated upon integrated photonics, technically known as *capacitive micromachined ultrasound transducer (CMUT)*.

This all allows for a much smaller spatial footprint, with many different frequency probes contained within one device. There is so much computational power on this chip that signal processing is also done right inside the probe, allowing for sophisticated imaging like color Doppler without the use of a much larger machine (**FIGURE 4.1**).

When the sound leaves the probe and "bounces back" off the tissue and returns to the same probe, the material generates a current. ***The probe itself thus both transmits and receives the sound*** (**FIGURE 4.2**).

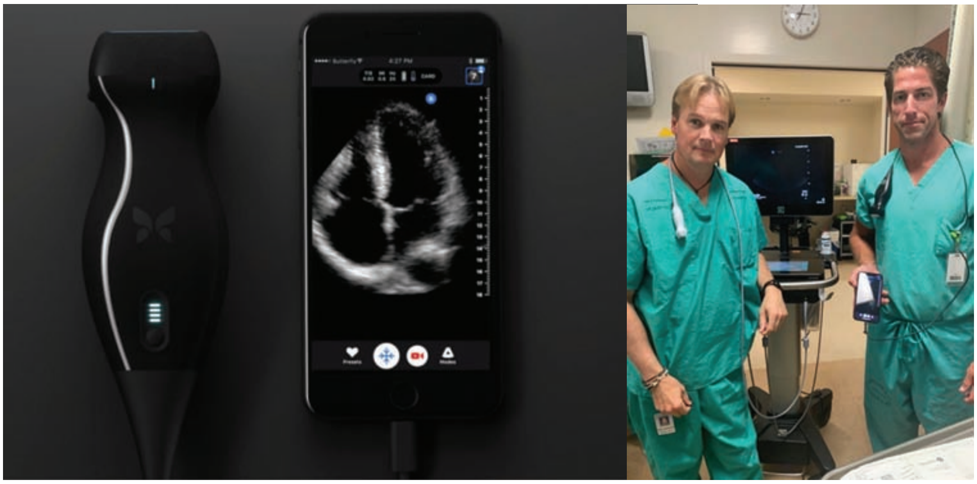


FIGURE 4.1 Smartphone-based ultrasound probe is now possible secondary to new silicon-based probes. Portability has never been more user-friendly in regard to ease of use and image quality. Also, one probe can act as many different frequency probes now—all using an internal 10-volt battery.

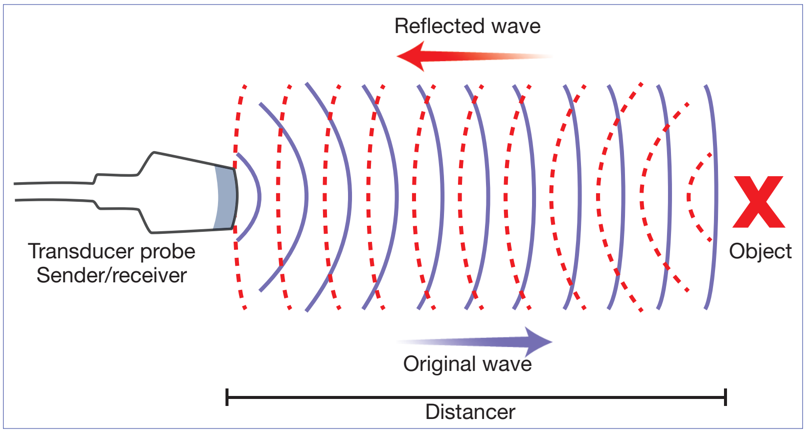


FIGURE 4.2 The transmitted ultrasound waves pass through the thin layer of skin, but bounce off fluids, tissues, internal organs, and bones in varying degrees, depending upon inherent tissue density/acoustic impedance. These reflected waves are received by the probe, which converts them into electric signals (piezoelectric crystals/silicon drum capacitive micromachined ultrasound transducer [CMUT]) and feeds them into the computer. The computer processes this information and performs quick calculations (a lot of them!) using the speed of sound and the time needed for the echo to reach the probe to create a real-time image of the inside of the human body.

The standard screen image that machines display is known as *B-mode* (also called *two-dimensional* or *gray scale*) and is created by an array of crystals (often 128 or more) embedded across the face of the transducer. Each crystal produces a scan line that is used to create an image or frame, which is refreshed many times per second to produce a moving image on the screen. Silicon drum CMUT devices do not use B-mode (absence of crystals) and because of the plethora of increased sensors (>9,000) the image quality is more silky.

PHYSICS

The speed of ultrasound does not depend on its frequency but rather the medium, or tissue, it is traveling in. Generated sound waves travel faster in dense materials and slower in compressible materials. In bone, sound waves travel about 3,400 m/sec, in soft tissue they travel about 1,500 m/sec, and in air they travel 330 m/sec. ***Acoustic gel is used as a coupling medium because air is an impenetrable barrier to ultrasound, and fluid offers the least resistance.***

Attenuation

When ultrasound waves interact with the tissue medium, attenuation occurs. **Attenuation is the loss of the sound wave caused by the absorption of ultrasound energy by conversion to heat**. Reflection, refraction, and scattering also result in reduced beam penetration (**FIGURE 4.3**). Attenuation is increased when:

- The distance from the sound waves to the transducer increases
- Higher frequency transducers are used
- When there are mismatches in acoustic impedance (see next section)

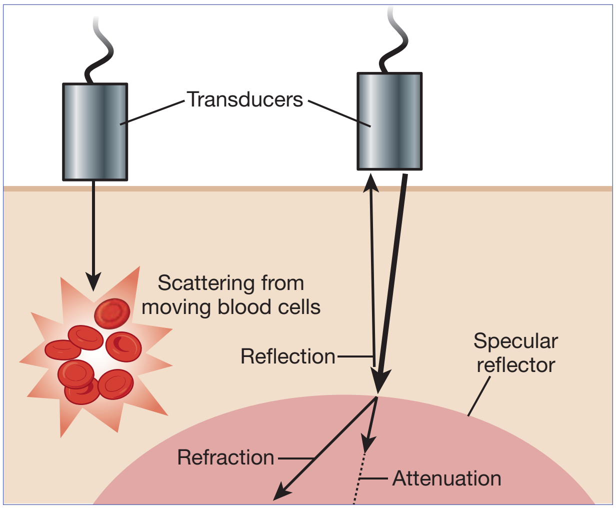


FIGURE 4.3 Interaction of ultrasound waves with an organ: Once the beam has passed through the skin, it is attenuated continuously as it travels as a function of depth. Upon hitting an interface, part of the beam is reflected and the remaining transmitted beam is refracted at an angle based on the change in speed. Scattering can occur off of small targets, like red blood cells, which can provide important information about circulatory diseases.

Acoustic Impedance

Acoustic impedance is a measure of how ultrasound traverses a tissue; it depends on the density of the medium and the relative propagation velocity of the sound wave traveling through the medium. ***In essence, it is the resistance to propagation of ultrasound waves***. This varies according to the density of the material through which the ultrasound passes. When the material is denser, then the particles are closer and more sonographic waves will reflect back to the crystals/silicon drums within the probe and fewer will penetrate through this medium. Fluid allows more sound waves through than solid material (since it is less dense) so fewer ultrasound waves will reflect back from fluids and more can go through this medium. This means that fluids will thereby produce an echogenic “black” image. Bones reflect more sound waves than fluid and produce a bright “white” image; therefore, a black acoustic shadow (void of waves) will be present behind a white outer surface. ***Air is a strong ultrasound beam reflector, making it difficult to visualize structures behind it*** (**BOX 4.1**).

A large difference in acoustic impedance among mediums due to their density is referred to as *acoustic impedance mismatch*; there is a corresponding difference in their ability to propagate ultrasound waves. ***The greater the acoustic mismatch, the greater the percentage of ultrasound beam reflected (similar to sound traveling through air hitting a wall and bouncing back).*** Examples of large acoustic impedance mismatch are soft tissue–bone interface and soft tissue–air interface.

BOX 4.1 Increasing Order of Tissue Acoustic Impedance

Air (highly reflective)
Fat
Water
Soft tissue (average)
Liver
Kidney
Blood (stationary, as flowing blood scatters the sound waves)
Muscle
Bone

Note: Air has the lowest acoustic impedance, yet it is the highest reflector of ultrasound waves.

TRANSDUCERS

Ultrasound transducers come in various sizes, shapes, and frequencies. Lower frequency ultrasound has better penetration and hence visualizes deeper organs, but at lower resolution. Higher frequency ultrasound provides better images, but it does not visualize deep structures well. The face of the transducer, or footprint, is where the sound waves are transmitted. Convex transducers are curved and ideal for abdominal imaging or in areas where rocking the transducer will improve visualization. Linear transducers are flat and generally offer higher frequencies and are used for imaging small body parts (testicles, breast, thyroid, superficial imaging, etc.). Appropriate transducer selection is based on the depth of the area of interest and anatomical region (**FIGURE 4.4**).

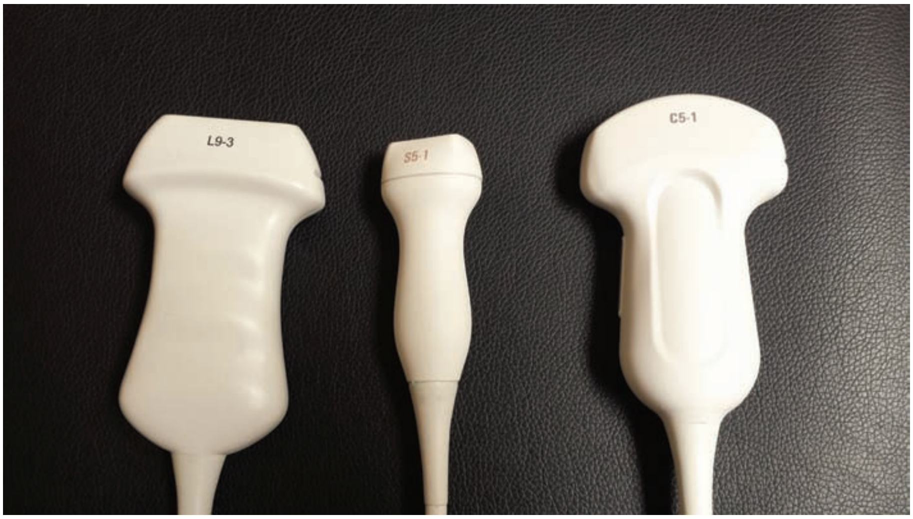


FIGURE 4.4 Transducers are constructed to use different frequencies and footprints to enable appropriate imaging based on body region and depth to the area of interest. Linear transducers are more suitable for superficial imaging (*far left*). Curved transducers (*far right*) are more suitable for imaging the abdomen as the transducer can be rocked. Phased-array probes have a small footprint in order to be used in intercostal acoustic windows (*middle*).

Equipment Maintenance

Ultrasound transducers must be cleaned with an appropriate disinfectant after each use. Using an autoclave, gas, or other cleaning methods may damage your transducer. When using ultrasound for needle guidance, do not allow sharp objects, such as scalpels and cauterizing knives, to touch transducers or cables. ***Transducers contain crystals so it is important not to bump them on hard surfaces.*** Silicon drum CMUT-based probes are far less fragile. Be sure to follow the manufacturer's instructions and/or national guidelines when using disinfectants with transducers. General guidelines call for a low-level disinfectant when used on intact skin surfaces. High-level disinfectant should be used for intracavitary and nonintact skin use with the appropriate probe cover.

IMAGING

Sonography offers the ability to image dynamically and in multiple patient positions. Patients can be evaluated in the supine, prone, left or right lateral decubitus, erect, or oblique positions.

Two-dimensional ultrasound is used to visualize a plane that is then shown on the screen. An indicator or "notch" on the probe is used to orient the user to the orientation of the plane on the screen. This is displayed on the screen as a manufacturer's emblem or a symbol. ***This is usually in the upper left of the screen for most ultrasound indications, but the orientation is changed to the upper right of the screen for most cardiac indications.*** This is an important difference for POCUS users to be aware of. The imaging plane may be directed by the user in any anatomical plane on the patient or area of interest (i.e., gallbladder): sagittal, coronal, transverse, or a combination (oblique). Movement of the probe can recreate three-dimensional organs or change fields of view. Normal movements include the following:

- Slide (translation): Move in a plane along the surface, keeping the probe at 90° to the surface
- Rock (tilt or heel-toe): Tilt the probe in a plane by adjusting the probe off of 90°
- Sweep (move): Move out of the plane, keeping the probe at 90°
- Fan (angle): Angle the probe out of the plane by adjusting the probe off of 90°
- Rotate: Move along a clockface while keeping the probe at 90°

Sagittal (Longitudinal)

The transducer orientation for a sagittal longitudinal plane has the indicator in the 12 o'clock position in relation to the organ or area of interest. The sound waves are transmitted from either the usual anterior approach or a posterior approach. The superior aspect of the region is displayed on the left side (corresponding to indicator) and inferior aspect on the right side of the sonographic image. The sagittal (longitudinal) plane does not demonstrate the organ in a lateral dimension (**FIGURE 4.5**).

Coronal

The transducer orientation for a coronal plane has the indicator in the 12 o'clock position in relation to the organ or area of interest. The sound waves are transmitted from the right or left side of the body (e.g., the flank/kidney). The superior aspect of the region is displayed on the left side (corresponding to indicator) of the image and inferior aspect on the right side. This plane does not depict the anterior or posterior aspect of the organ (**FIGURE 4.6**).

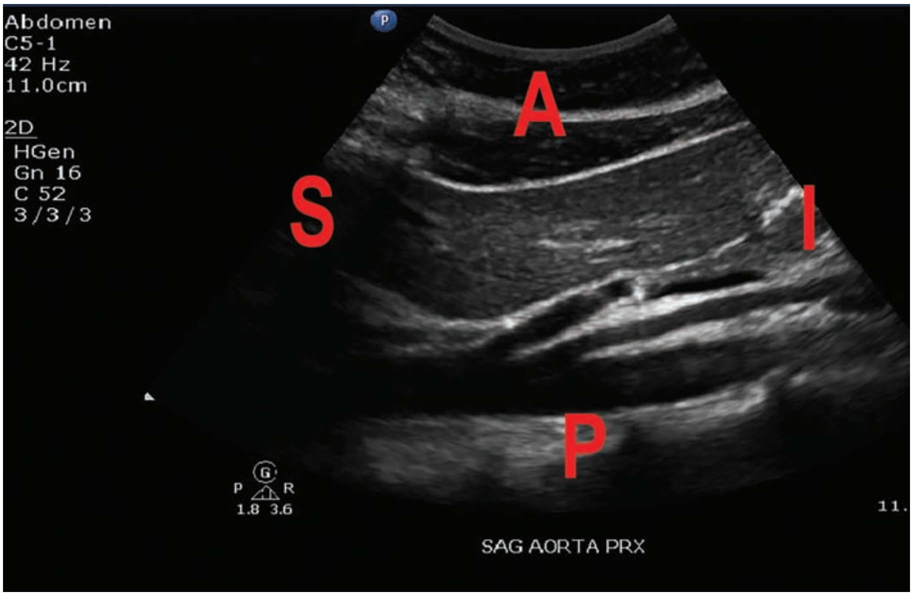


FIGURE 4.5 Ultrasound image showing the sagittal (longitudinal) plane. S: superior (patient's head), I: inferior (patient's feet), A: anterior, and P: posterior.

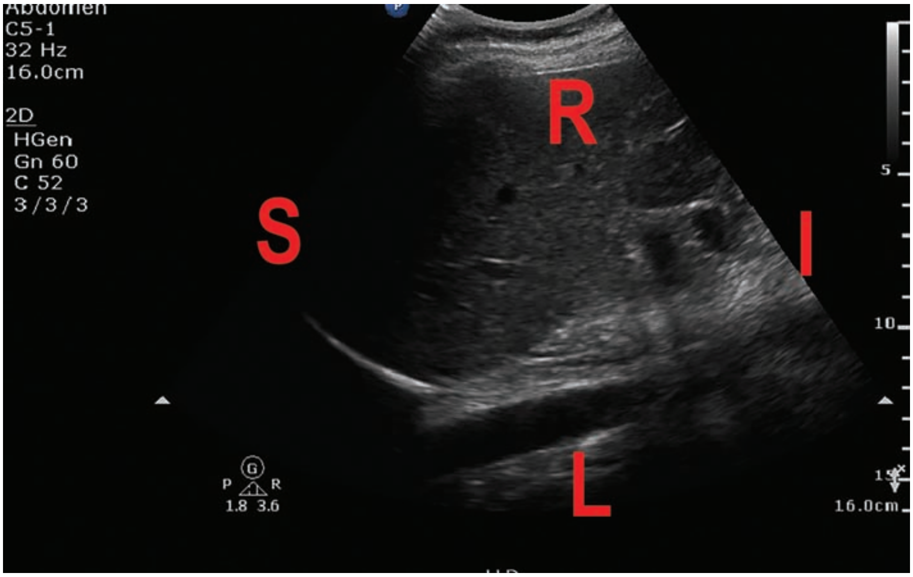


FIGURE 4.6 Ultrasound image depicting the coronal plane. S: superior (patient's head), I: inferior (patient's feet), R: right, and L: left. Right is at the top of the image because the patient is in a left lateral decubitis position and the transducer is on the patient's right side.

Transverse (Anterior or Posterior Surface)

The transducer orientation for the transverse plane has the indicator in the 9 o'clock position in relation to the organ or area of interest. The indicator will point to the patient's right from the anterior approach. The sound waves are transmitted from either the anterior (usual) or posterior dimension. From the typical anterior view, the patient's right side is displayed on the left of the screen (corresponding to indicator) and patient's left side is seen on the right side of the screen when sound waves are transmitted from an anterior approach (similar to viewing CT scans; **FIGURE 4.7**). In a posterior view, the patient's left is seen to the left of the screen and the patient's right is on the right side of the screen.

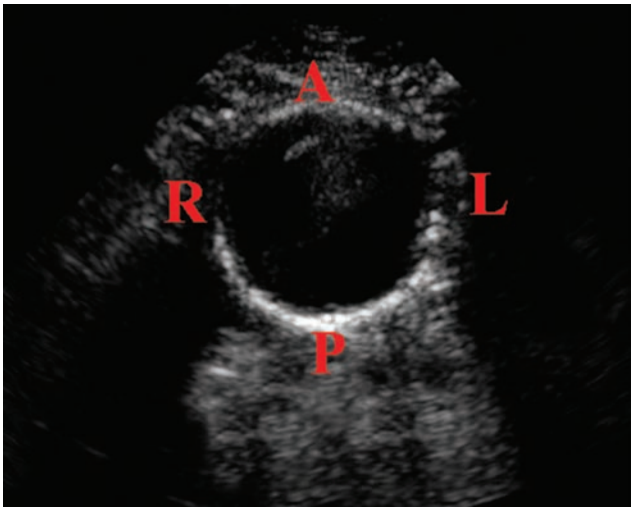


FIGURE 4.7 Ultrasound image of the transverse plane. R: patient's right, L: patient's left, A: anterior, and P: posterior. Note this picture represents an abdominal aortic aneurysm; as stated in this chapter, think of viewing the transverse plane as if you were standing at the patient's feet looking toward their head, analogous to studying a CT scan.

DEFINITIONS OF SONOGRAPHIC CHARACTERISTICS

Because of the way the ultrasound image is created, descriptive terms are used based on the echogenicity, or strength of the sound wave reflected back to the transducer (instead of brighter and darker). Echogenicity is not something that can be measured, like mass or length. In order to effectively communicate sonographic findings, the use of specific terms is required. Normal tissues and organ structures have a characteristic appearance *relative to surrounding structures*. A normal relationship in this inherent sonographically detected echogenicity of various organs means that there is no apparent pathology, though subtle pathology may not be appreciated. In diseased states, this organ-specific and characteristic echogenicity is abnormal (**FIGURES 4.8** and **4.9**). This underlies the importance of using correct nomenclature in describing findings for a precise diagnosis. Common ultrasound terms are defined in (**TABLE 4.1**).

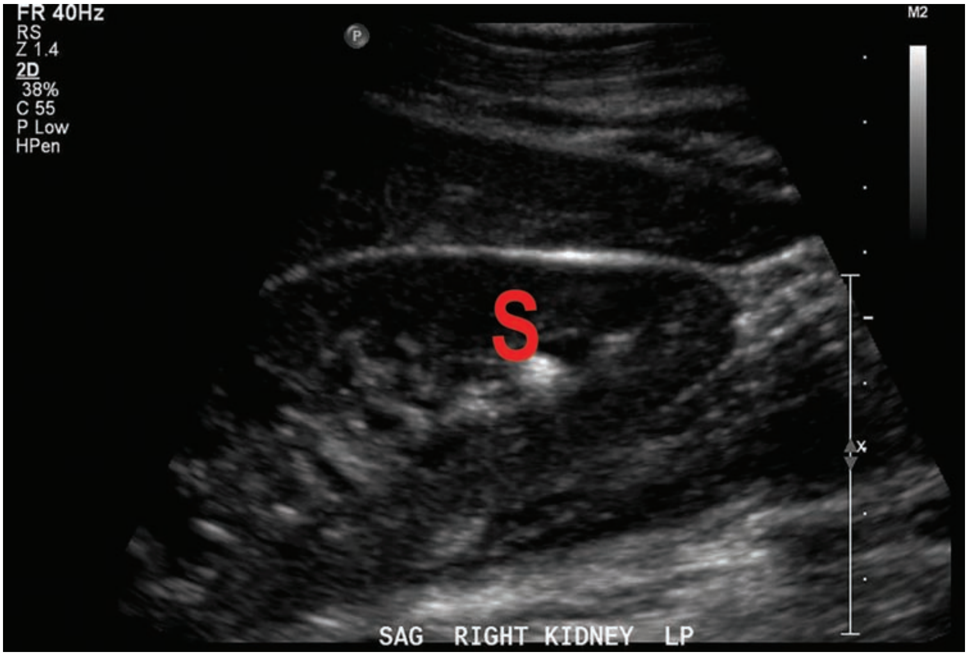


FIGURE 4.8 A renal stone. The stone (labeled as "S") is hyperechoic. It has an increased (brighter) echogenicity than the surrounding kidney.

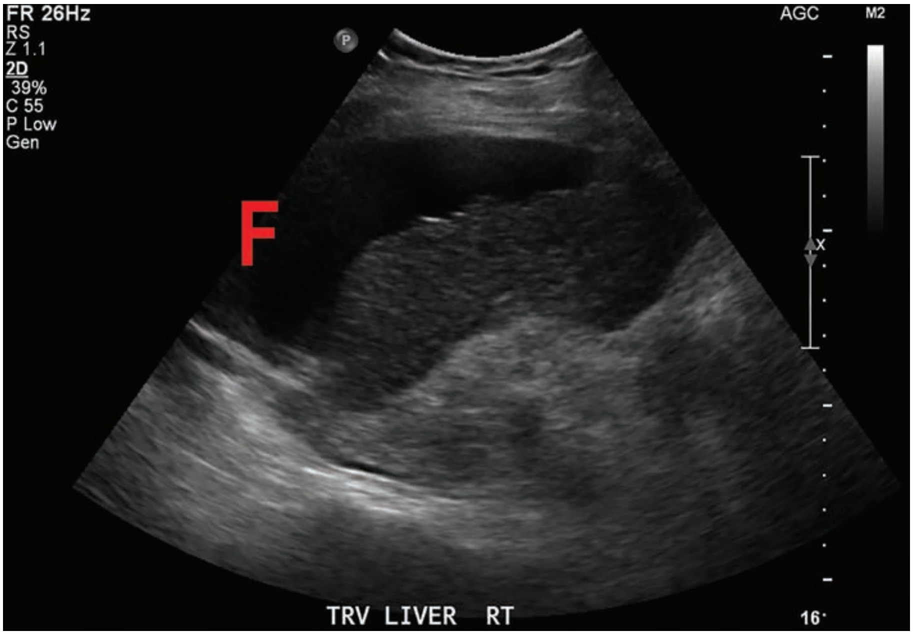


FIGURE 4.9 Free fluid around the liver. Note that the fluid is anechoic and homogeneous.

TABLE 4.1 Terms Describing Echogenicity

Term	Definition	Example
Hypoechoic	Not as bright as surrounding tissues	Muscle is less bright than fat
Hyperechoic	Brighter echoes than surrounding tissues	Renal stones (see **FIGURE 4.8**) are brighter than renal parenchyma
Isoechoic	Same intensity as surrounding tissues	The liver and right kidney cortex may appear isoechoic in normal patients
Anechoic	Echo free	Simple cyst, urinary bladder, blood (within vessel), free fluid (see **FIGURE 4.9**)
Homogenous	Structures have uniform echo intensity	Normal liver or spleen
Heterogenous	Structures have varied echo characteristics	Normal kidney exhibits different echotextures (cortex, medulla, and sinus)

RESOLUTION

Resolution refers to the ability to identify two or more objects or points as separate entities within a special plane. It is measured in units of distance such as millimeters. The higher the resolution, the smaller the distance that can be differentiated. There are three types of resolution that pertain to ultrasound imaging: axial, lateral, and temporal. Axial (or longitudinal) resolution is the ability to recognize two different objects at slightly different depths from the transducer along the longitudinal axis of the ultrasound beam. The resolution at any point along the beam is the same. Axial resolution is improved with the use of higher frequency transducers but comes at the expense of penetration. Higher frequencies, therefore, are used to image structures close to the transducer.

Lateral resolution is the ability to distinguish objects that are side by side or two points in the direction perpendicular to the direction of the sound waves. Lateral resolution is generally poorer than axial resolution and is dependent on beam width. The ultrasound machine assumes that any object visualized originates from the center of the beam, so two objects side by side cannot be distinguished if they are separated by less than the beam width. Lateral resolution is improved with optimal focal zone placement.

Temporal resolution is the ability to detect that an object has moved over time and is dependent on frame rate. Temporal resolution is improved by minimizing depth and narrowing the sector (sector angle) to the area of interest.

ARTIFACTS

Artifacts can be defined as any structure in the ultrasound image that does not have a corresponding anatomic tissue structure. They are common in ultrasound images because they are often the sequelae of the physical properties of ultrasound itself. All ultrasound machines make various assumptions in generating an image. These assumptions include the following: The ultrasound beam only travels in a straight line with a constant rate of attenuation, the depth of a reflector is accurately determined by the time taken for sound to travel from the transducer to the reflector and return, and the speed of sound in all tissues is 1,540 m/sec. In order to provide technically accurate images, the operator needs to have a basic knowledge of artifacts and how to reduce or eliminate them. The following artifacts are the most commonly encountered during routine sonographic exams.

Reverberation artifact occurs when the ultrasound wave is repeatedly reflected between two highly reflective surfaces. For example, if the transducer acts as another reflective surface to a returning echo, this echo will then be re-reflected and retrace itself, resulting in an artifactual image identical to the real image, but at twice the distance from the transducer. Due to the process of attenuation, each subsequent echo is weaker than the first. To avoid this, move the transducer to a slightly different location and avoid the strong reflecting surface.

Mirror-image artifact is a type of reverberation artifact that occurs in highly reflective air with fluid interfaces such as the lung/diaphragm. The first image is displayed in the correct position, whereas a false image is produced on the other side of the reflector due to its "mirror"-like effect.

Posterior-enhancement artifact occurs when the area behind an echo-weak or echo-free structure appears brighter (more echogenic) than its surrounding structures. This occurs because neighboring signals had to pass through more attenuating structures and return with fainter echoes. This explains why cysts or fluid collections demonstrate a brighter echo deep to the fluid as the sound wave is traveling faster through it. To avoid this, move the transducer to a slightly different position or adjust time-gain resolution (**FIGURE 4.10**).

An *acoustic shadow* results when the sound beam is unable to pass through an area posterior to, or beyond, a strongly reflecting or attenuating structure. It is seen, for example, deep to areas of calcification such as stones or bones. *Tissue dropout* occurs due to poor beam penetration and the shadow obscures the area (**FIGURE 4.11**).

If too much gain is used it is "overgained" (bright from too much overall gain), which can create or obscure information. This is of great importance when attempting to evaluate for renal stones (**FIGURE 4.12**).

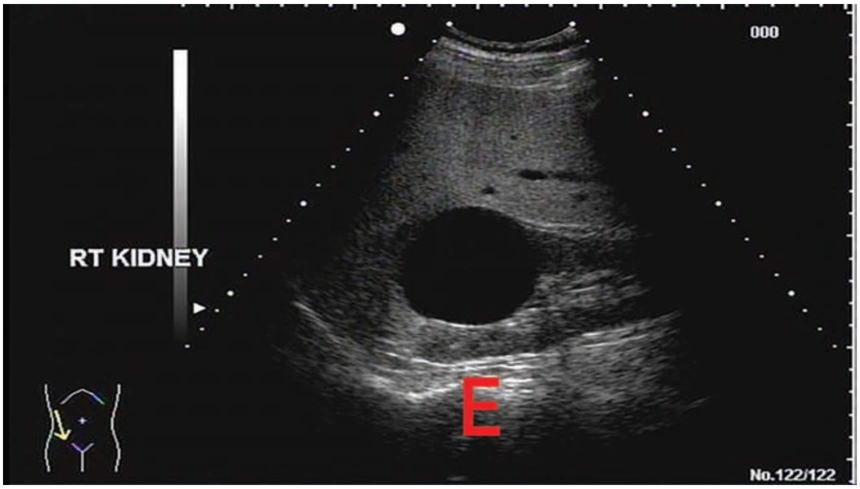


FIGURE 4.10 Arrow indicates a simple renal cyst. Note the enhancement (E) of the sound beam posterior to the cyst. The speed of sound is faster in the cyst (simple fluid) than the organs (liver and kidney).

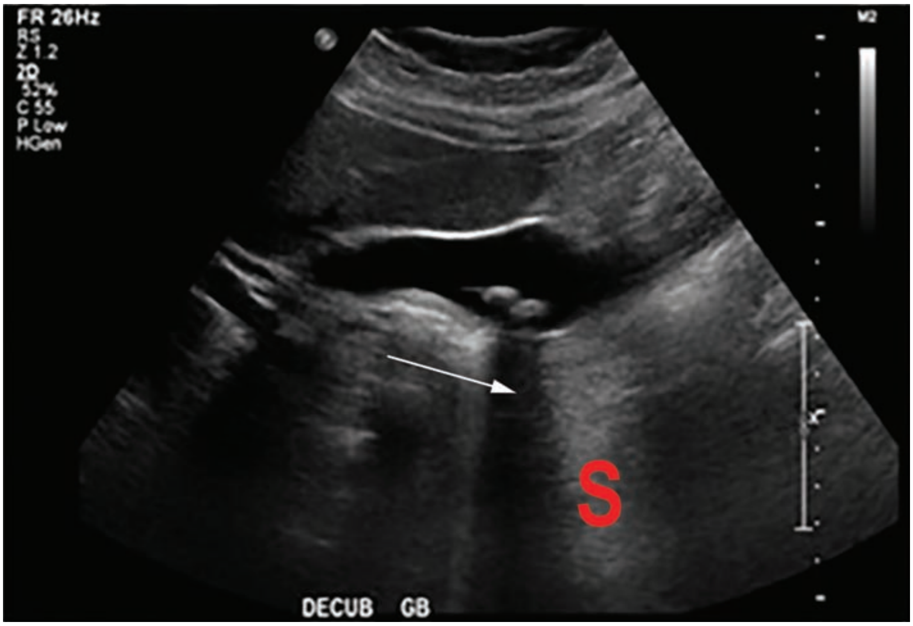


FIGURE 4.11 S: Acoustic shadow caused by a gallstone (*arrow*).

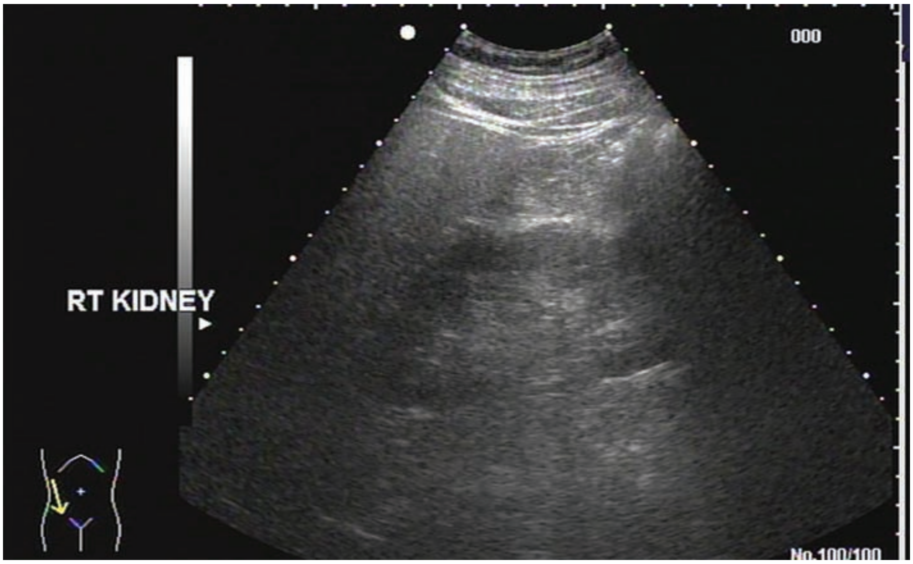
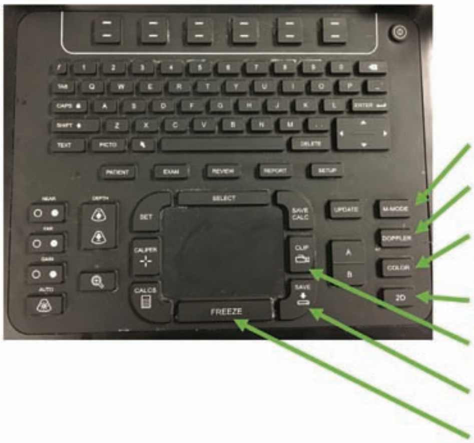


FIGURE 4.12 Image is overgained (bright from too much overall gain), which makes it difficult to assess renal anatomy.

KNOBOLOGY

Some general guidelines when recording ultrasound images can assist in achieving more optimal image quality and increased clinical utility. It is important to minimize gain to differentiate needed structures. Excess gain can lead to poor image quality, making it difficult to tell important structures apart (either due to excess gain, which makes the entire image hyperechoic, or insufficient gain, which makes the image hypoechoic). If certain depths of the image have excess or insufficient gain, it is possible to adjust the time gain compensation or near–far gain settings. ***Limiting depth to the imaged organ or area of interest can lead to better visualization***.

FIGURES 4.13 and **4.14** depict images of two sample keyboards with function descriptions.



Scan Modes: Bedside ultrasound interfaces allow selection of different scan modes

M-mode: Single scan line graphed over time

Doppler: Special mode demonstrating flow/movement

Color-flow: Two-dimensional image with color highlighting flow/movement

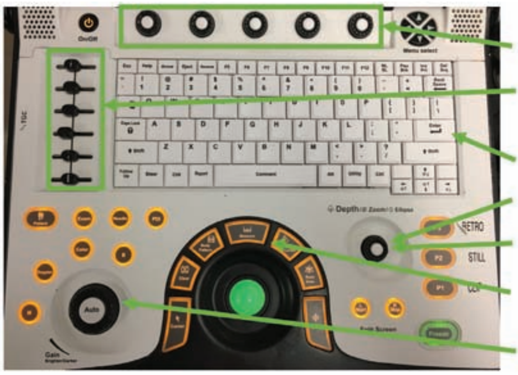
B-mode: Two-dimensional image display

Clip: Save video

Still: Save image

Freeze: Hold current image on screen

FIGURE 4.13 Sample keyboard with scan modes and image storage.



Control/Interface Keys: Select from menu items

Time-Gain Compensation or NearFar Gain Adjustment: Adjust gain applied to different image fields (by depth)

Alphanumeric Keyboard: Enter text

Depth: Adjust imaging depth

Zoom: Magnify image (digital zoom)

Annotations and Measurement: Mark image and record distances

Gain: Adjust ultrasound amplification

FIGURE 4.14 Sample keyboard with scan adjustment and controls.

CLINICAL USES OF ULTRASOUND

Advancements in technology have fueled the clinical application for the use of ultrasound and, as such, ultrasound use has grown exponentially over the past decade. The increased use of medical ultrasound can also be attributed to rising demand for point-of-care testing (POCT) in general and the increasing number of diagnostic and therapeutic procedures available. ***The expediency of bedside and real-time diagnosis of various pathologies, including life-threatening ones; precision enhancement for many procedures; prevention of transportation delays; avoidance of radiation; and potential aversion of costly additional imaging modalities are some major factors in the emergence and continued growth of clinical sonography.***

EDUCATION POINTS

- Acoustic impedance of tissue increases with density; therefore, softer tissues—like fat or muscle—have lower impedance than bone or tissue masses.
- Air is a strong ultrasound beam reflector, which makes it difficult to visualize structures behind it.
- Lower frequency ultrasound has better penetration and hence visualizes deeper organs, but at lower resolution, whereas higher frequency ultrasound provides better images, but it does not visualize deep structures well.
- Limiting depth to the imaged organ or area of interest can lead to better visualization.
- Artifacts can be defined as any structure in the ultrasound image that does not have a corresponding anatomic tissue structure.
- The greater the difference between the acoustic impedances of the two materials at a boundary in the body, the greater the amount of reflection—two materials with the same acoustic impedance would give no reflection, whereas two with widely separated values (cartilage–air) would give much larger reflections.

PEARLS

- POCUS is easy to learn and simply requires practice.
- A key to success using this bedside modality is knowledge of anatomy and a keen sense of orientation in regard to the probe/screen.
- POCUS should be considered a visual stethoscope that is far more informative and accurate.
- POCUS is designed to answer focused questions (yes or no), whereas comprehensive sonographic examinations evaluate all organs in an anatomical region.
- In procedures that can be guided by ultrasonography, embrace this modality as it is the standard of care to do so.
- A distinct advantage of POCUS is that it gives immediate answers and, in time-sensitive pathologies (abdominal aortic aneurysm [AAA], ruptured ectopic pregnancies), there is a robust amount of literature showing a decrease in morbidity and mortality with its bedside use.
- POCUS examinations are generally performed by the same clinician who generates the relevant clinical question answered with POCUS and ultimately integrates the findings into the patient’s care; this offers a distinct advantage over formal sonographic exams.

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CHAPTER 5

Introduction to Diagnostic Ultrasound

Cara Kanter

BACKGROUND

Clinician-performed bedside ultrasound is a safe, efficient, and cost-effective tool that can aid in the rapid assessment and management of a myriad of patient presentations. Ultrasound education has grown exponentially across most medical fields and disciplines and its applications are continuing to expand at a rapid pace.

Clinician-performed ultrasound differs from radiology ultrasounds in that it is meant to answer a specific clinical question rather than serve as a comprehensive evaluation of an organ system. The clinician performing the study must be able to obtain the required views and interpret the study results in real time to aid in the diagnosis and management of the patient.

This chapter serves as an introduction to the core applications of diagnostic ultrasound, as outlined in the American College of Emergency Physicians (ACEP, 2016) Ultrasound Guidelines Policy Statement. Each section introduces a specific examination and describes the indications, required views, and selected pathology for the novice learner. It is not meant to serve as a comprehensive review and does not discuss nonclinical aspects of clinician-performed ultrasound such as credentialing, quality assurance, or billing.

There are few contraindications to bedside ultrasound, but the most important one to be aware of is the delay to definitive management such as the operating room. ***If your patient requires emergent surgery or transfer, do not delay their disposition to obtain ultrasound images***. If performing a bedside ultrasound examination will not delay the disposition of your patient—by all means—scan away!

Though covered in Chapter 4, Introduction to Ultrasound and Knobology, understanding image orientation cannot be overemphasized. Every ultrasound transducer has a probe marker along one side of its head, which corresponds to an indicator on the screen. This means that when we say, "Point the probe marker to the patient's left," the part of the screen near the indicator is toward the patient's left. Likewise, shallow structures on the body appear near the top of the screen, whereas deeper structures (far from the probe surface) appear near the bottom of the screen.

TRAUMA: THE FAST EXAM

The first reported use of ultrasound in trauma patients was in Europe in 1971 when it was used to detect free intraperitoneal fluid in blunt-trauma patients. The technique was introduced to North America in the early 1990s and the term *focused assessment with sonography for trauma (FAST)* was coined. Since then, FAST has replaced diagnostic peritoneal lavage (DPL) to become an initial screening modality for severe abdominal trauma in most trauma centers in the United States. Because of the high sensitivity/specificity, inner-user reliability, ease of use, and duration of the FAST study (3–5 minutes), DPLs have decreased from 9% to 1%, whereas CT utilization has decreased from 47% to 34%. Moylan et al. (2007) has shown that even in the normotensive blunt-trauma patient, 37% of patients with a positive FAST required therapeutic laparotomy (odds ratio = 44.6) versus 0.5% with a negative FAST. Finally, because the amount of hemoperitineum increases the sensitivity of detection (more fluid, easier to visualize), the astute clinician incorporates this in serial physical examinations (**TABLE 5.1**).

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

TABLE 5.1 The Accuracy of FAST Ultrasound in Traumatic Injuries Based Upon a 2019 Meta-Analysis of 4,263 Patients

Sensitivity	92.1%
Specificity	98.7%
Positive predictive value	90.7%
Negative predictive value	98.8%

Source: Data from Lee, C., Balk, D., Schafer, J., Welwarth, J., Hardin, J. Yarza, S.,…Hoffman, B. (2019). Accuracy of focused assessment with sonography for trauma (FAST) in disaster settings: A meta-analysis and systematic review. *Disaster Medicine and Public Health, 13*(5–6), 1059–1064. https://doi.org/10.1017/dmp.2019.23

The FAST examination is meant to rapidly identify free intraperitoneal, pericardial, and pleural fluid, which in the setting of trauma is always assumed to be blood. This exam is often the first modality taught to the beginning ultrasound student. The extended FAST (eFAST) examination also assesses the lungs for traumatic pneumothorax and has essentially replaced the FAST exam in the evaluation of traumatic patients (**FIGURE 5.1**).

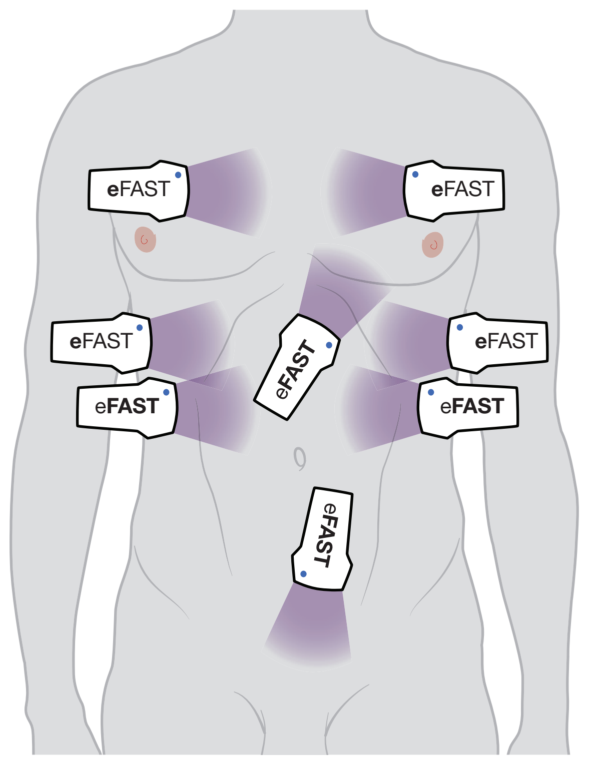


FIGURE 5.1 Required views for the eFAST examination.
eFAST, extended focused assessment with sonography for trauma.

Indications

- All blunt thoracoabdominal trauma
- All penetrating thoracoabdominal trauma

Required Views

- Six to eight views (**FIGURE 5.1**):
  - Morison's pouch/right upper quadrant (RUQ)
  - Subxiphoid/cardiac
  - Left upper quadrant (LUQ)
  - Suprapubic
  - Bilateral hemithoraces (eFAST)
  - In supine patients, midclavicular second intercostal views of the lungs

Preparation

- Probe choice: Curvilinear/abdominal probe
  - Can switch to phased-array/cardiac probe for subxiphoid view and linear/vascular probe for lung sliding (time permitting)
- Patient supine or in Trendelenburg position

Note that the peritoneal cavity is continuous and communicating in terms of peritoneal fluid movement as hemoperitoneum starts near the site of injury and flows along expected anatomic pathways (**FIGURE 5.2**). In the supine position, the most dependent portion of the abdomen is Morison's pouch (hepatorenal recess), and the most dependent portion of the pelvis is the pouch of Douglas (pelvic cul-de-sac). Hemorrhage from the liver typically flows in a caudal direction from the perihepatic spaces, into the hepatorenal recess, along the right paracolic gutter, and into the cul-de-sac, which is the rectouterine space in women and rectovesical space in men. Similarly, hemorrhage from the spleen typically flows in a caudal direction from the perisplenic spaces, into the splenorenal fossa, along the left paracolic gutter, and into the pelvis cul-de-sac.*

- Fluid flows downhill and respects boundaries—it must build up in one area before overflowing to an adjacent area.

---

*A peculiarity of the communication pathway in the peritoneal cavity is the left paracolic gutter, as it is actually separated from the pelvis by the phrenicolic ligaments; hence, splenic-injury blood must first spread to Morison's pouch (hepatorenal recess) before entering the pelvis.

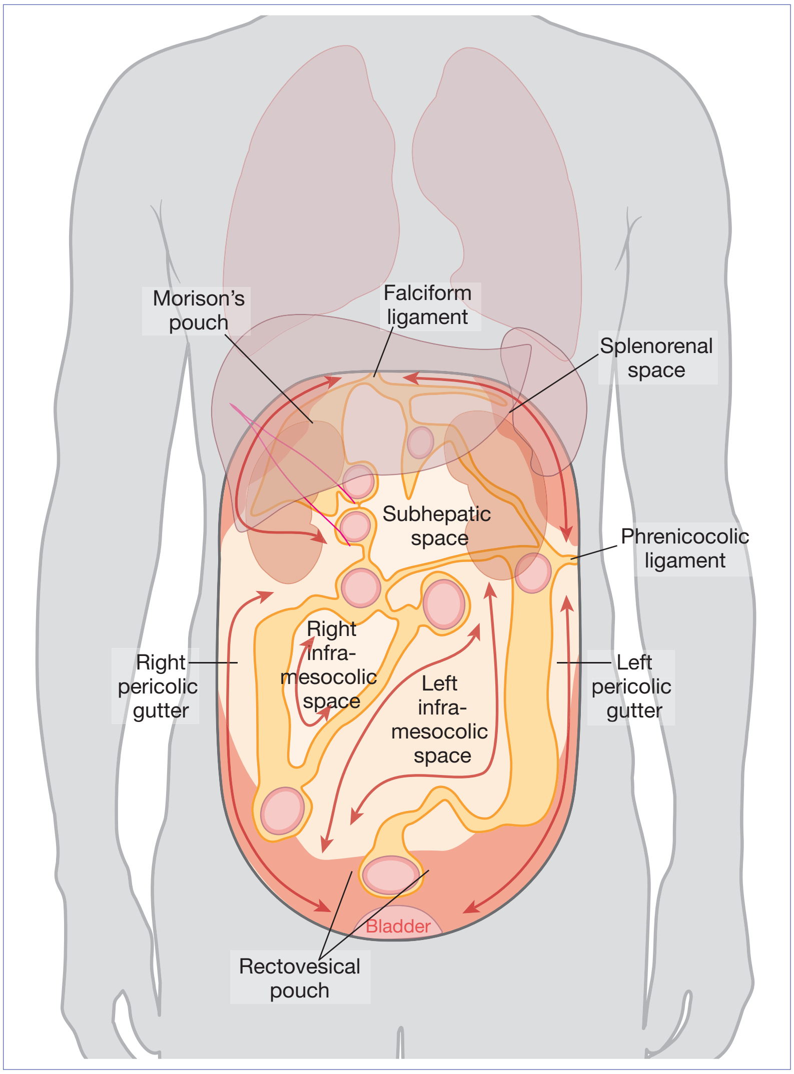

Morison's pouch
Falciform ligament
Splenorenal space
Subhepatic space
Phrenicocolic ligament
Right pericolic gutter
Right infra-mesocolic space
Left infra-mesocolic space
Left pericolic gutter
Bladder
Rectovesical pouch

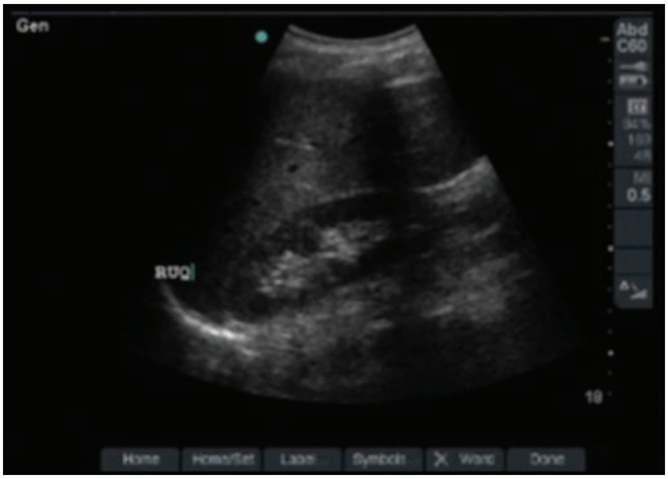
FIGURE 5.2 Flow of blood in hemoperitineum.

- There is no open space in the peritoneum, only ***potential space*** and, as such, fluid must wedge itself between visceral organs and the parietal peritoneum as it follows the contour of the organ and ultimately tapers off, creating a "pointy" appearance.

Procedure

MORISON'S POUCH/RIGHT UPPER QUADRANT

- Longitudinal image with probe marker toward the patient's head (**VIDEO 5.1** and **FIGURE 5.3**)
- Identify the hepatorenal fossa, a potential space between the liver and the right kidney (**FIGURE 5.4**).
- Sweep the entire area from right to left (posterior to anterior).
- Be sure to view: Posterior pleural space, diaphragm, inferior edge of liver.
- Blood will appear as dark (hypoechoic) fluid collecting primarily in Morison's pouch (**see FIGURE 5.11**).


Gen
Abd C60
RUQ
0.5
19

VIDEO 5.1 Normal FAST study.

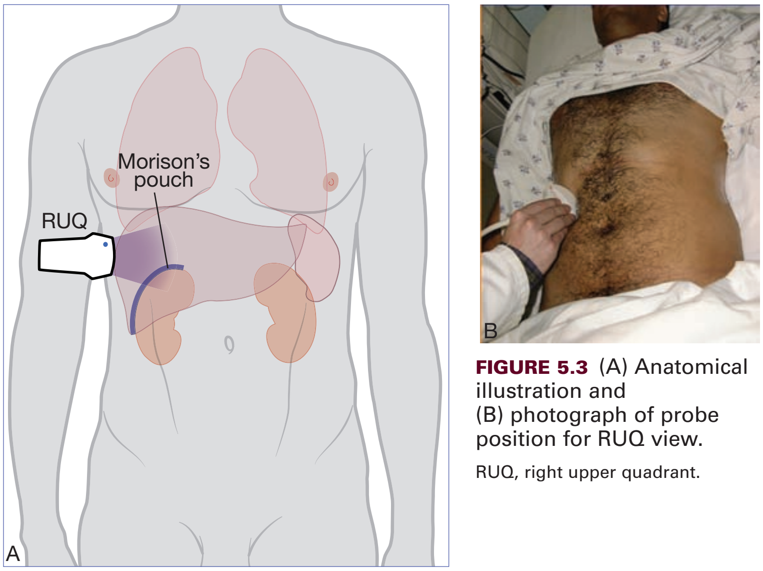


FIGURE 5.3 (A) Anatomical illustration and (B) photograph of probe position for RUQ view.

RUQ, right upper quadrant.

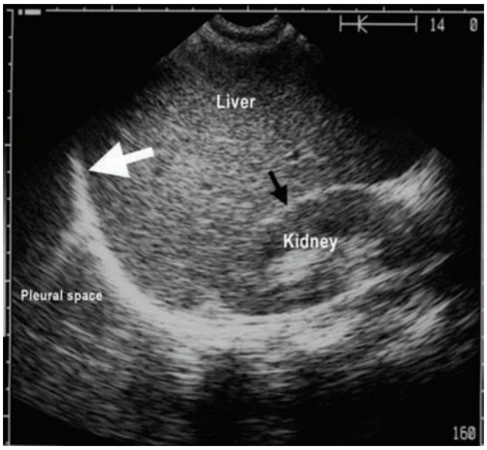


FIGURE 5.4 Normal RUQ view. The black arrow identifies Morison's pouch, the potential space between the liver and the right kidney. The white arrow identifies the diaphragm.

RUQ, right upper quadrant.

SUBXIPHOID/CARDIAC

- Place the probe in the transverse plane just inferior to the xiphoid process, with the probe marker toward the patient's right side (**FIGURE 5.5**).
  - When using the cardiac probe, the marker should be facing the patient's left side.
- Grip the probe from the top and create a shallow angle, nearly parallel to the patient's skin.
- Apply gentle downward pressure, looking "up and under" the xiphoid process toward the patient's thorax.
- Use the liver as an acoustic window and adjust depth so the heart appears below the liver.
- Adjust gain so blood in ventricles appears black.
- Be sure to visualize both the superior and inferior pericardial borders (**FIGURE 5.6**).

LEFT UPPER QUADRANT

- Technically more difficult to visualize than the RUQ as the spleen provides a smaller acoustic window than the liver and there is more interference from adjacent bowel gas
- Longitudinal image with probe marker toward the patient's head
- Position the probe at the posterior axillary line around the 10th rib space (**FIGURE 5.7**).

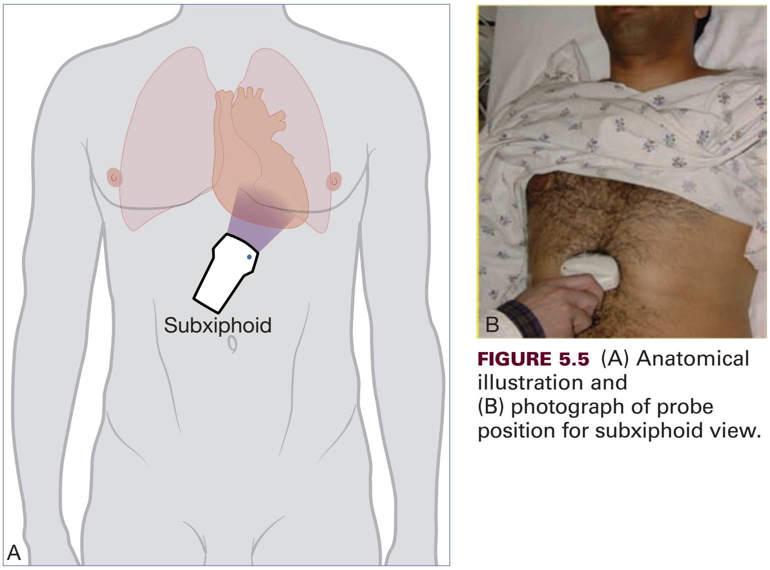


FIGURE 5.5 (A) Anatomical illustration and (B) photograph of probe position for subxiphoid view.

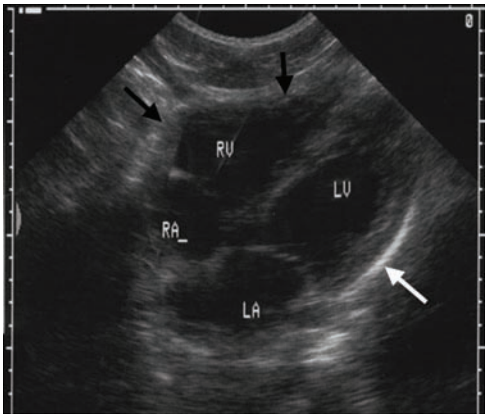


FIGURE 5.6 Normal subxiphoid view. The anterior pericardial border is identified by the black arrows and the posterior pericardial border is identified by the white arrow.

LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

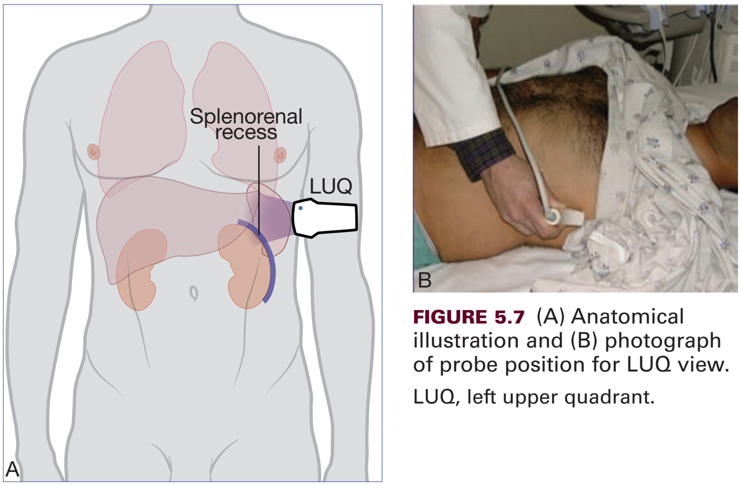


FIGURE 5.7 (A) Anatomical illustration and (B) photograph of probe position for LUQ view.

LUQ, left upper quadrant.

- Angle the probe to avoid rib shadowing.
- Modest inspiration improves the view.
- Sweep the entire area from right to left (anterior to posterior).
- Be sure to view: Posterior pleural space, diaphragm, spleen, splenorenal space, left kidney (**FIGURE 5.8**)
- Free fluid does NOT reliably accumulate in the splenorenal space and often accumulates above the spleen (below the diaphragm) and in the left paracolic gutter (**see FIGURE 5.12**).

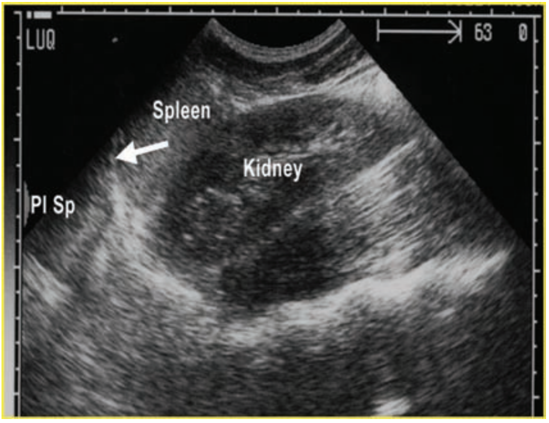


FIGURE 5.8 Normal LUQ view. The white arrow identifies the diaphragm.

LUQ, left upper quadrant.

SUPRAPUBIC VIEW (FIGURES 5.9 AND 5.10)

- The bladder provides the acoustic window for this view. It is best to obtain this view with a full bladder and before a urinary catheter is in place.
- Women: Scan in longitudinal plane with probe marker toward the patient's head (**FIGURE 5.9A**).
  - Visualize the bladder, uterus, and pouch of Douglas (rectouterine pouch; **FIGURE 5.10A**).
  - Blood will pool behind the uterus in the pouch of Douglas (**see FIGURE 5.13A**).
  - Sweep the entire area from right to left.
- Men: Scan in the transverse plane with the probe marker toward the patient's right (**FIGURE 5.9B**).
  - Visualize the bladder, prostate, and rectovesicular pouch (**FIGURE 5.10B**).
  - Blood will pool around the prostate creating the "bow-tie sign" (**see FIGURE 5.13B** and **C**).
  - Sweep the entire area from cephalad to caudad.

BILATERAL HEMITHORACES

- When scanning the RUQ and LUQ, be sure to look above the diaphragm for fluid in the pleural space (**see FIGURES 5.4** and **5.8**).
- Refer to the lung section of this chapter for information on how to assess the lungs for pneumothorax.

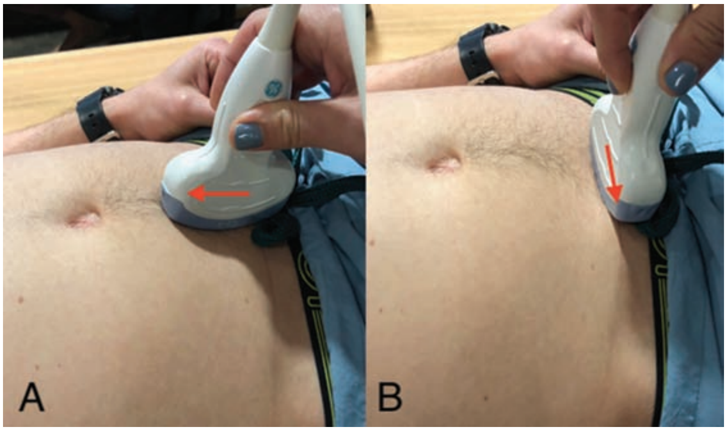


FIGURE 5.9 Probe position for subrapubic view. (A) Longitudinal view. (B) Transverse view.

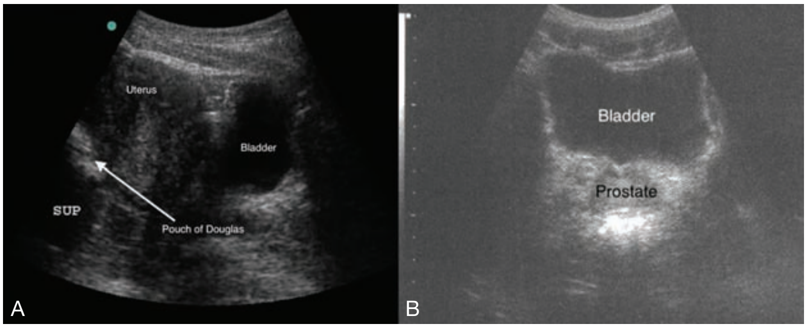


FIGURE 5.10 Normal suprapubic views in (A) a female and (B) a male patient.

SELECTED PATHOLOGY

Hemoperitoneum

- In the trauma context, any free peritoneal fluid indicates hemoperitoneum until proven otherwise.
- Free fluid will appear as dark hypoechoic areas with sharp edges and will fill dependent potential spaces such as Morison's pouch and/or the pelvis (rectouterine in females/rectovesical in males).
- Clotted blood may appear hypo- or hyperechoic.
  - It is important to realize that blood appears as simple hypoechoic fluid, similar to the anechoic fluid of ascites. It is distinguished from the latter sonographically by the presence of foci of increased echogenicity in the hypoechoic fluid. These foci of mixed echogenicity may be strand-like or more mass-like, and represent clot formation, as this is what stagnant blood does. As the clot maturates, it becomes increasingly organized and uniformly echogenic.
  - In one study of a surgically proven pelvic hemoperitoneum, intraoperative-proven clotted blood was proven 60% of the time sonographically by demonstrating echogenic "masses" among anechoic/hypoechoic blood (**FIGURES 5.11**, **5.12**, **5.13**).

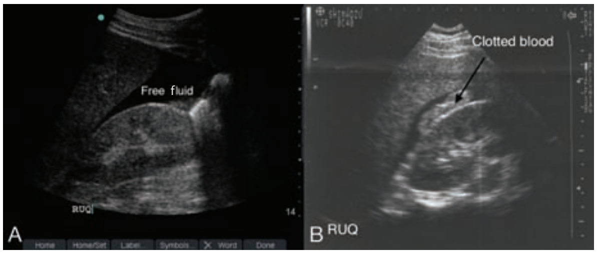


FIGURE 5.11 Positive RUQ views. (A) Hypoechoic free fluid in the hepatorenal fossa (Morison's pouch) in a trauma patient. (B) Hyperechoic blood clot (*black arrow*) with surrounding hypoechoic free fluid.

RUQ, right upper quadrant.

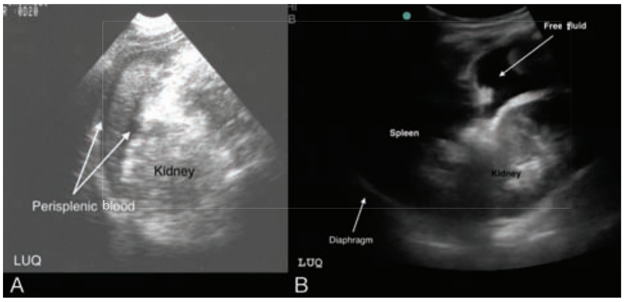


FIGURE 5.12 Positive LUQ views. (A) Perisplenic blood in a patient status post assault. (B) Free fluid in the splenorenal space in a gunshot-wound patient.

LUQ, left upper quadrant.

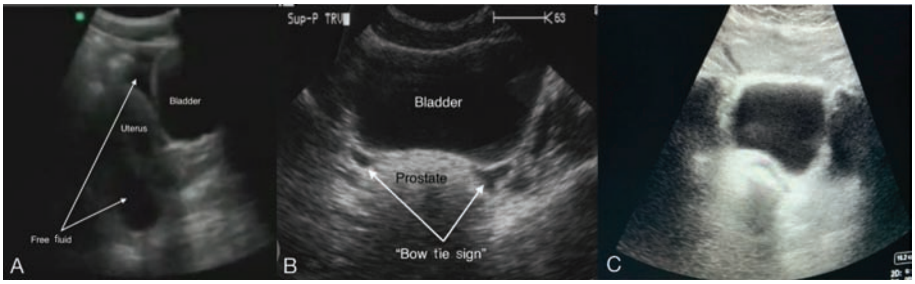

Bladder
Uterus
Free fluid
A
Sup-P TRV
K63
Bladder
Prostate
"Bow tie sign"
B
C

FIGURE 5.13 Positive suprapubic views. (A) Longitudinal view in a female trauma patient. Note the free fluid in the rectouterine space (pouch of Douglas) and the vesicouterine space. (B) Transverse view in a male trauma patient. Note the free fluid in the rectovesicular space creating the "bow-tie sign." (C) Large amount of fluid (blood) in a blunt traumatic patient in the rectovesicular space creating a prominent "bow-tie sign."

Hemopericardium

- Anechoic fluid in the pericardial space is diagnostic of a pericardial effusion (**FIGURE 5.14**).
- In the trauma setting, any pericardial effusion identified is a hemopericardium until proven otherwise.
- Appearance of the cardiac chambers may be very distorted in tamponade.

Hemothorax

- Be sure to look above the diaphragm on the RUQ and LUQ views for free fluid in the thorax (**FIGURE 5.15**).
- In the trauma context, free fluid in the thorax is a hemothorax until proven otherwise.

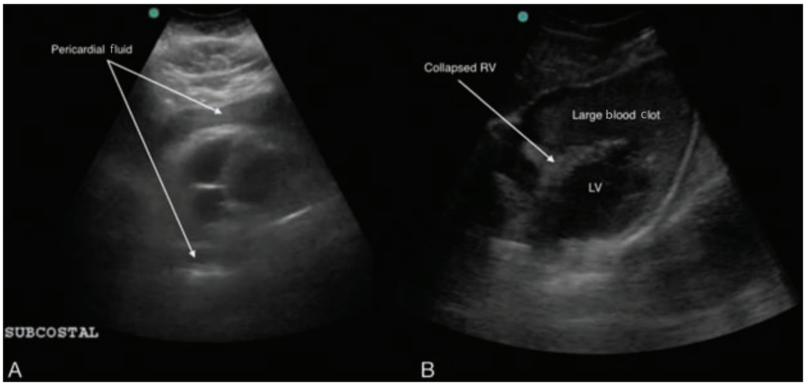

Pericardial fluid
SUBCOSTAL
A
Collapsed RV
Large blood clot
LV
B

FIGURE 5.14 Positive subxiphoid views. (A) Hypoechoic fluid in the pericardium; in a trauma patient, this is assumed to be a hemopericardium. (B) Hypoechoic pericardial fluid with large hyperechoic blood clot in a trauma patient who was stabbed in the chest.

LV, left ventricle; RV, right ventricle.

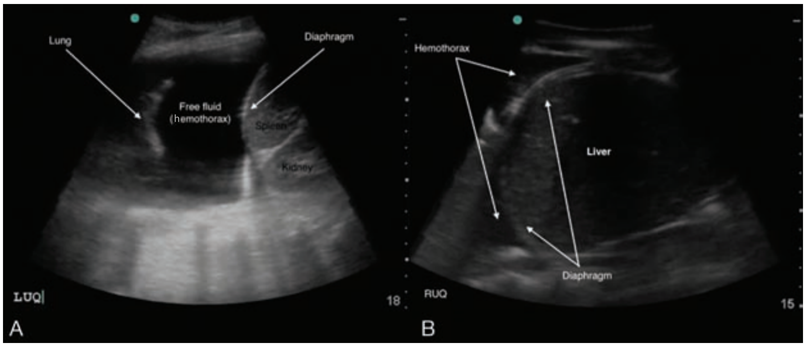

Lung
Diaphragm
Free fluid (hemothorax)
Spleen
Kidney
LUQ
18
A
Hemothorax
Liver
Diaphragm
RUQ
15
B

FIGURE 5.15 Positive hemithorax views. (A) LUQ view of pleural fluid in a trauma patient. (B) RUQ view of a hemothorax in a patient who suffered a stab wound to the chest.

LUQ, left upper quadrant; RUQ, right upper quadrant.

Pearls

- Each view should take 30 to 60 seconds to obtain, and the entire study should take no more than 5 minutes.
- ***Do not confuse an indeterminate view with a negative view! If you are unable to visualize the entirety of one of your views, you cannot call it negative.***
- Beware of retroperitoneal hemorrhage as it is not well visualized on the FAST exam.
- Beware of patients with delayed presentations, as intraperitoneal blood is often heterogeneous in regard to its echogenicity; it may appear isoechoic with solid organs, though there will usually still be anechoic and hypoechoic areas.
- In most cases, hemoperitoneum appears anechoic or hypoechoic to adjacent solid organs; however, its echogenicity may be slightly hyperechoic with the presence of blood clots. Mobile echoes may be appreciated on real-time scanning. In supine patients, hemoperitoneum often collects at the hepatorenal fossa and pelvic cavity, which are the most dependent portions of the abdomen and pelvis, respectively.
- The amount of hemoperitoneum may be estimated using the number of spaces with fluid present: The more spaces with fluid, the greater is the amount of hemoperitoneum.
- Failure to visualize the kidney on the FAST exam should raise the suspicion of perinephric space hemorrhage in the context of severe abdominal trauma; perinephric space hematoma has an amorphous heterogeneous echogenic appearance on sonography.
- ***The FAST exam has been studied as a tool to stratify patients either to go for CT scan or to the operating room; in general, positive intraperitoneal fluid in the unstable patient indicates immediate surgery, whereas positive intraperitoneal fluid in the stable patient indicates CT.***
- Even a stable patient with negative FAST exam may require additional workup and imaging.

CARDIAC

Indications

- Cardiac arrest
    - In a prospective manner, Breitkreutz et al. (2007) have shown that there is a high rate of cardiac activity in patients thought to be in pulseless electrical activity (PEA; 74.5%) or asystole (35%). Suspected PEA is often simply profound shock, and asystole is often fine ventricular fibrillation (VF). Identification of cardiac activity in these scenarios changes the interventions that can be applied and may lead to improved outcomes. This has been further validated by Gaspari et al. (2016), who found prospectively that 54% of patients with suspected PEA and 10% of suspected asystole patients had mechanical activity.
- Unexplained hypotension or dyspnea
- Suspected tamponade
- Suspected aortic dissection

Required Views

- Four common views (**FIGURES 5.16**, **5.17**, and **5.18**)
    - Subxiphoid (“subcostal”) four-chamber view
    - Parasternal long-axis (PLAX) view
    - Parasternal short-axis (PSAX) view
    - Apical four-chamber view

Preparation

- Probe choice: Phased array (cardiac probe)
    - The footprint, or the face of this transducer, is small, allowing it to be easily manipulated in between the intercostal spaces, avoiding the rib shadows.
    - Use curvilinear (abdominal) probe for subxiphoid view.
- Patient positioning: Sitting, supine, or left lateral decubitus

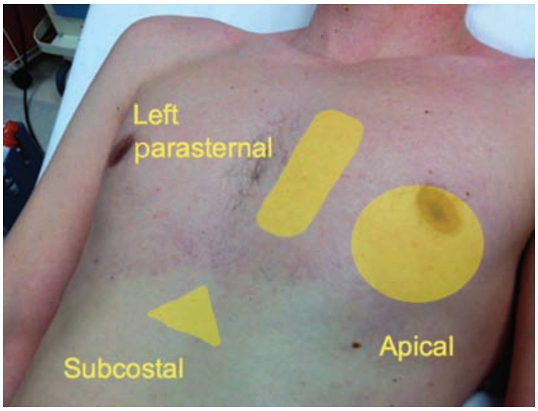


FIGURE 5.16 Probe placement for the four basic cardiac views and cardiac anatomy.

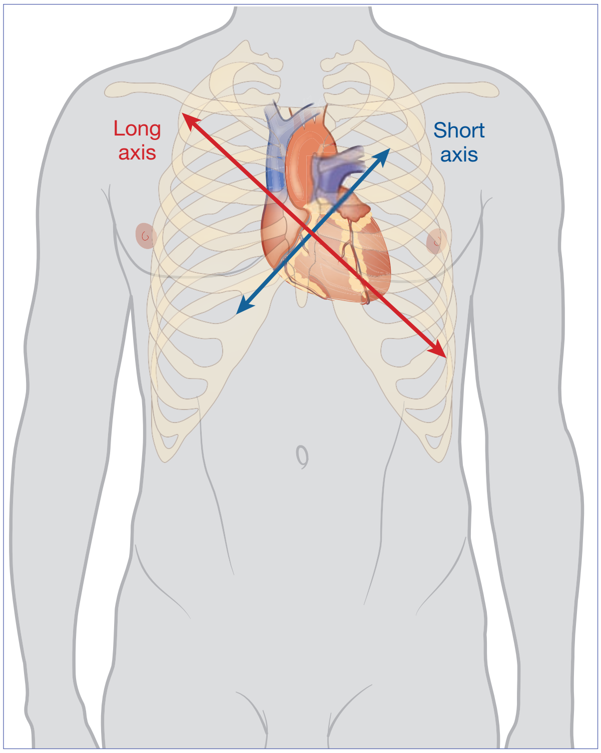

Long axis
Short axis

FIGURE 5.17 Normal position of the heart from a bird's-eye view. Note that the LV is posterior to the RV and that the long-axis vector is 150 degrees (southeast).

LV, left ventricle; RV, right ventricle.

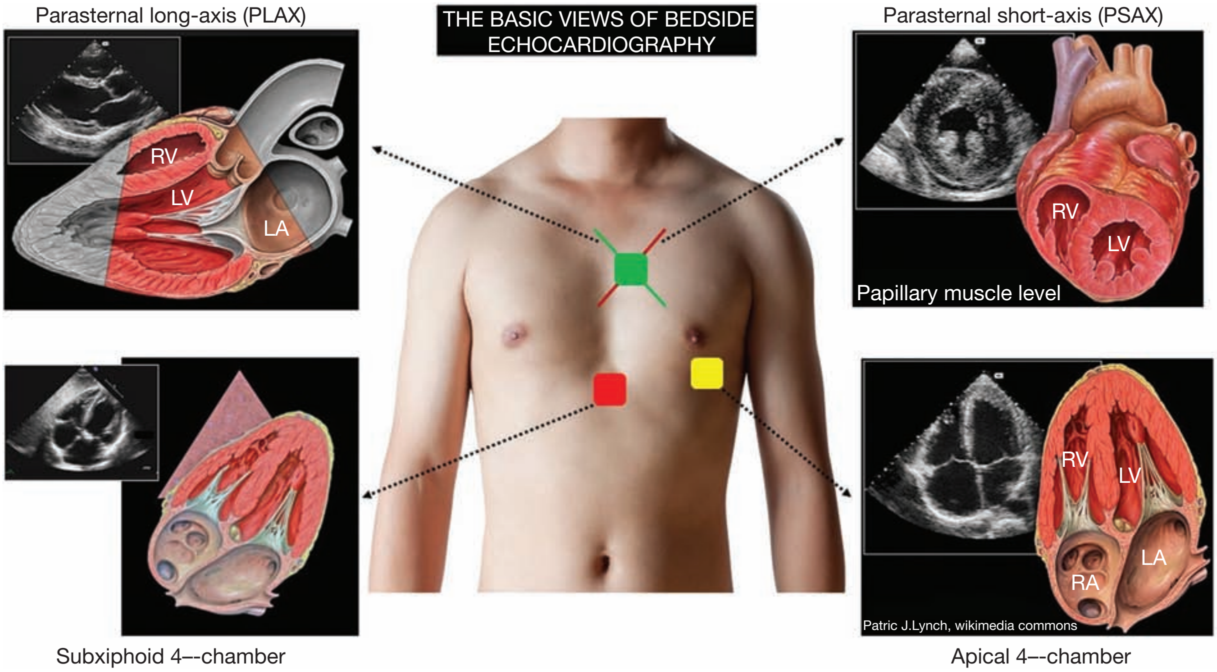

Parasternal long-axis (PLAX)
THE BASIC VIEWS OF BEDSIDE ECHOCARDIOGRAPHY
Parasternal short-axis (PSAX)
RV
LV
LA
RV
LV
Papillary muscle level
RV
LV
LA
RA
Patric J.Lynch, wikimedia commons
Subxiphoid 4–-chamber
Apical 4–-chamber

FIGURE 5.18 The four common views of the heart with POCUS. One must conceptualize the basic cardiac chamber anatomy, combined with image orientation, to fully appreciate these images. In the beginning, this may be daunting; however, once this is conquered, going forward, learning becomes much more simplified.

POCUS, point-of-care ultrasound.

Source: Reproduced with permission from Abhilash Koratala, MD, FASN. Retrieved from https://nephropocus.com/2019/06/14/focus-on-focus-the-4-basic-views-of-the-heart

Procedure

SUBXIPHOID ("SUBCOSTAL") FOUR-CHAMBER VIEW

Assesses for presence of pericardial effusion/tamponade and global heart function.

- Place the probe in the transverse plane just inferior to the xiphoid process with the probe marker toward the patient's left side (**FIGURE 5.19**).
  - When using the abdominal probe, the marker should be facing the patient's right side (**FIGURE 5.20**).
- Grip the probe from the top and create a shallow angle, nearly parallel to the patient's skin.
- Apply gentle downward pressure, looking "up and under" the xiphoid process toward the patient's thorax.
- Use the liver as an acoustic window and adjust depth so the heart appears below the liver.
- Adjust gain so blood in ventricles appears black.
- Be sure to visualize both the superior and inferior pericardial borders (**VIDEO 5.2**)

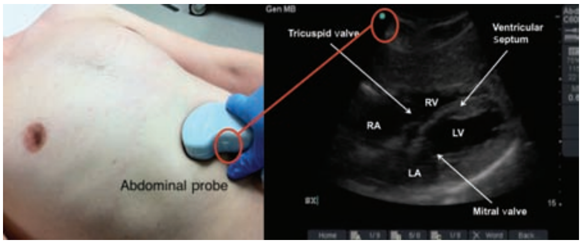


FIGURE 5.20 Subxiphoid view of the heart achieved with the abdominal probe. Note that the indicator is facing the patient's right side and corresponds to the left side of the screen.

LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

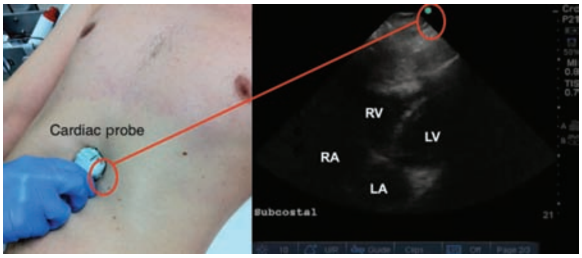
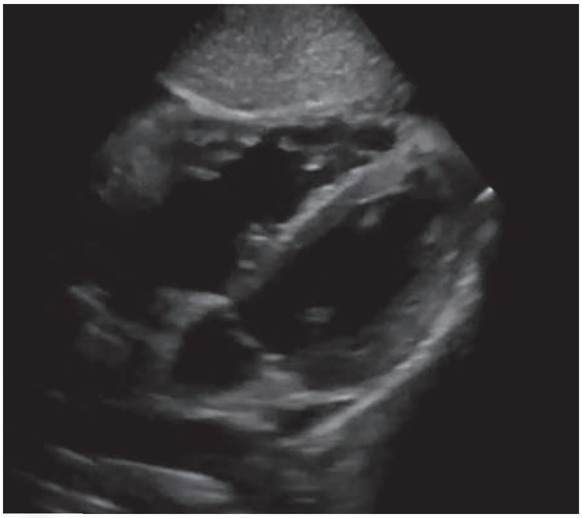


FIGURE 5.19 Subxiphoid view with cardiac probe. Note that the indicator is facing the patient's left side and corresponds to the right side of your screen. This probe position is in contrast to other organ views.

LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.



VIDEO 5.2 Normal subxiphoid view.

PLAX

Proper alignment is essential to obtain accurate measurements of the aortic outflow tract (AOFT), aorta, left atrium (LA), left ventricular (LV) wall thickness, and LV systolic and diastolic diameters. Both the mitral valve and the aortic valves should be seen and will be roughly in the center of the image, stacked on top of each other. The base of the LV, but not the apex, should be visible. The right ventricular outflow tract (RVOT) will be seen on the top of the image.

- Position the probe in the left second, third, or fourth intercostal space just lateral to the sternum.
- Point the probe marker toward the patient's right shoulder (**FIGURE 5.21**).
- Identify the LA, mitral valve, LV, interventricular septum, AOFT, aortic valve, and right ventricle (RV).
  - You may need to rotate your probe slightly clockwise or counterclockwise, or move up or down a rib space to visualize all of these structures in a single view (**VIDEO 5.3A**).
- Look for pericardial effusion.

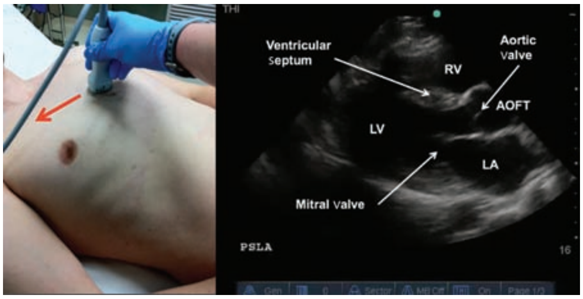
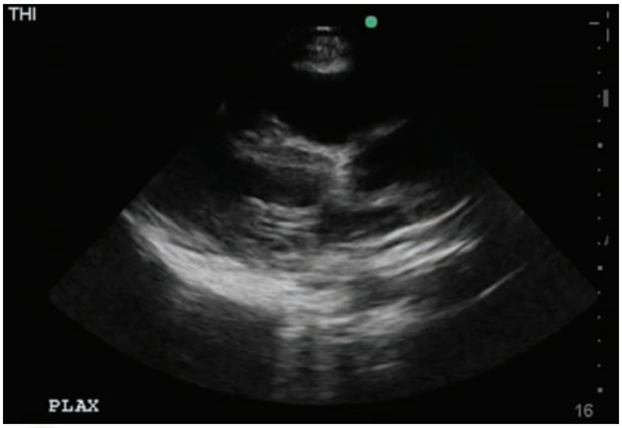


FIGURE 5.21 Probe placement for parasternal long-axis view and key structures. Note the indicator is facing the patient's right shoulder.

AOFT, aortic outflow tract; LA, left atrium; LV, left ventricle; RV, right ventricle.

- Make a visual estimate of ejection fraction (EF) based on global heart function, although many devices can automatically calculate this.
    - Assess how close the anterior leaflet of the mitral valve gets to the interventricular septum during diastole.
        - Good EF greater than 50%
        - Moderate EF 30% to 50%
        - Poor EF less than 30%
- Measure the internal diameter of the AOFT at its largest diameter (**FIGURE 5.22**).
    - Less than 3.5 cm is normal
        - Argues strongly against type A dissection
    - Greater than 4 cm is abnormal
    - Undulating intimal flap is pathognomonic of dissection



VIDEO 5.3A Normal cardiac study displaying PLAX, PSAX, and apical four-chamber views.

PSAX

***Focuses on obtaining an image of both ventricles in cross-section, which allows for evaluation of global systolic function and regional wall-motion abnormalities* (see VIDEO 5.3A).**

- Position the probe in the left second, third, or fourth intercostal space just lateral to the sternum.
- Point the probe marker toward the patient's left shoulder (**FIGURE 5.23**).
- Move the probe downward and leftward along the long axis of the heart toward the apex until the papillary muscles within the LV come into view (mid-LV PSAX; **see FIGURE 5.23**).
- Identify the RV to the left of the screen, the interventricular septum, and the LV to the right of the screen.
- Make sure the LV is circular and not ovoid in shape by angling the probe toward the apex.
- LV walls should contract concentrically.
    - Note any areas of the LV wall that are not contracting as vigorously; these are regional wall-motion abnormalities.
- Visually estimate global cardiac function as well as relative chamber size.
    - RV should be smaller than LV.
    - The septum should bow into the RV, indicating higher pressure in the LV, which is normal.
        - When the septum bows into the LV, it is a marker of increased right-sided pressures, which, in the right clinical context, can be concerning for pulmonary embolism (PE). This is referred to as the "D-sign" (**see FIGURE 5.28; VIDEO 5.3B**).

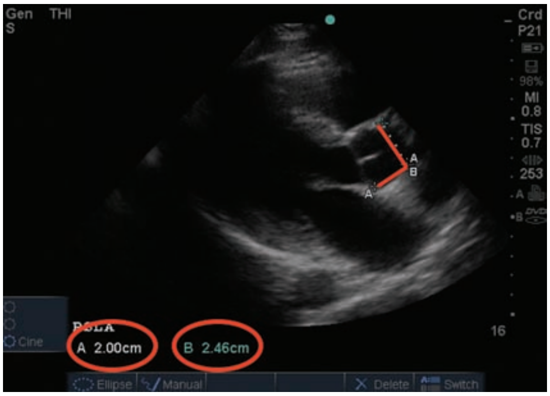


FIGURE 5.22 Normal aortic root diameter measuring 2.46 cm (measurement B). In this case, the measurement is taken 2 cm distal to the aortic valve annulus (measurement A).

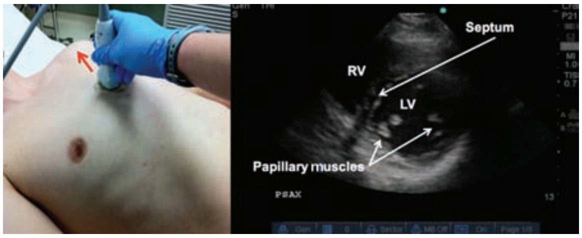
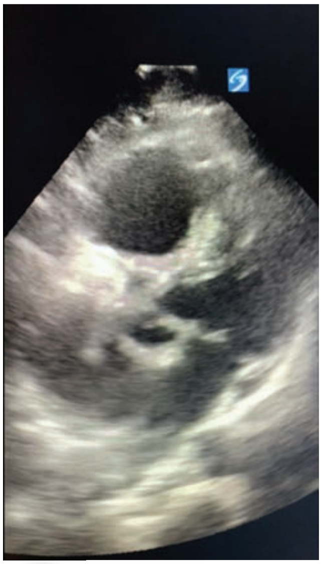


FIGURE 5.23 Parasternal short-axis view. Note that the probe indicator is facing the patient's left shoulder. Note the papillary muscles within the LV and the circular shape of the LV with the septum bowing toward the RV.

LV, left ventricle; RV, right ventricle.



VIDEO 5.3B Apical four-chamber view demonstrating a massive PE.

APICAL FOUR-CHAMBER VIEW

This view demonstrates all four chambers of the heart and is ideal for assessing relative chamber size, to study the heart valves, and several other aspects of the heart. This is in many ways the most intuitive and comprehensive view of the heart (**VIDEO 5.3A**).

- Position the probe at the point of maximum impulse (PMI).
- Point the probe marker toward the patient's left axilla (**FIGURE 5.24**).
- Center your image over the apex of the heart so the septum is directly perpendicular to the probe footprint.
  - *A technically good-quality apical view will have the interventricular septum running straight down the middle of the screen.*
- Adjust your angle so that all four chambers and both atrioventricular valves are visible in a single image.
- Identify the ventricles at the top of the screen and the atria at the bottom of the screen.
- Identify the mitral and tricuspid valves.
- Visually estimate global cardiac function and relative chamber size.
  - Right heart should be smaller than left heart.
    - Increases in right heart chamber size indicate increased right-sided pressures, which, in the right clinical context, may be concerning for PE.
- Assess for pericardial effusion.

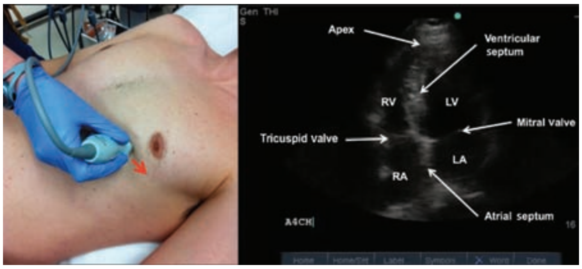


FIGURE 5.24 Apical four-chamber view. Note that the probe indicator is facing the patient's left axilla. Note the septum in the middle of the screen, perpendicular to the probe footprint.

LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

SELECTED PATHOLOGY

Pericardial Effusion

- This occurs when fluid accumulates in the pericardial space and compresses the cardiac chambers.
- Can progress to cardiac tamponade with hemodynamic compromise, obstructive shock, and ultimately death without intervention.
- A diagnosis of cardiac tamponade requires:
  - Pericardial effusion on ultrasound
  - Evidence of diastolic RV collapse (**FIGURE 5.25**)
    - This is beyond the scope of this section.
- Differentiating epicardial fat from a pericardial effusion can be challenging; fatty tissue can be characterized by:
  - Heterogeneous echo texture
  - Coordinated movement in conjunction with the myocardium
  - *Failure to track around the heart, especially at the apex and posteriorly (most dependent portion of the pericardium)*
    - Exceptions are loculated or focal effusions and therefore multiple views are recommended.

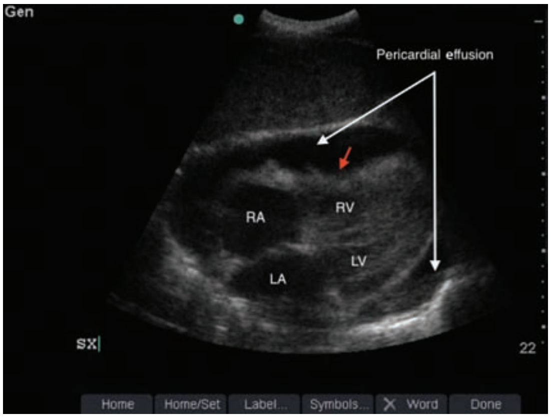


FIGURE 5.25 Subxiphoid view of a large pericardial effusion. The red arrow indicates bowing in of the RV. If this is seen during ventricular diastole, it is a marker of tamponade physiology.

LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Systolic Dysfunction

- Depressed global cardiac function is measured as a reduction in systolic EF (**FIGURE 5.26**).
    - Good EF is greater than 50%.
    - Moderate EF is 30% to 50%.
    - Poor EF is less than 30%.
- In longstanding systolic dysfunction, all cardiac chambers may be pathologically dilated.
- EF can be visually estimated from various cardiac views:
    - PLAX
        - Assess how close the anterior leaflet of the mitral valve gets to the interventricular septum during diastole.
    - PSAX and subxiphoid
        - Assess how vigorously the ventricular walls contract.
        - Assess how cardiac chamber size changes during systole.
            - Minimal change in size = poor EF

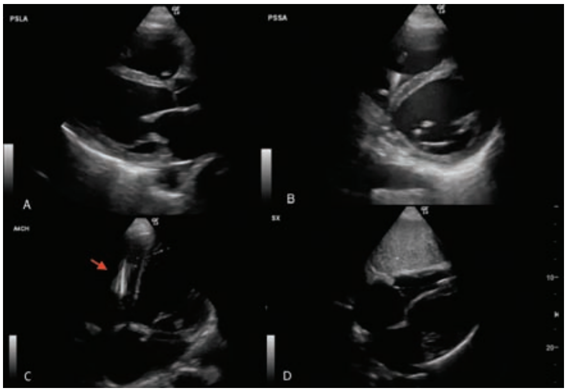


FIGURE 5.26 Cardiac views in a patient with known systolic dysfunction and an EF of 15%. Note the dilated chamber size throughout.

(A) PLAX. Note the anterior of the mitral valve is far from the septum in diastole. (B) PSAX view. (C) Apical four-chamber view. Note the presence of an AICD wire in the right ventricle (*red arrow*). (D) Subxiphoid view.

AICD, automatic implantable cardioverter defibrillators EF, ejection fraction; PLAX, parasternal long-axis view; PSAX, parasternal short axis.

Type A Dissection

- Involves the ascending aorta
- Surgical emergency
- Vast majority of type A dissections involve the aortic root and are associated with aortic root widening
    - Less than 3.5 cm is normal.
        - Argues strongly against type A dissection
    - Greater than 4 cm is abnormal.
    - Undulating intimal flap is pathognomonic of dissection.
    - Can also be associated with pericardial effusion (**FIGURE 5.27**).

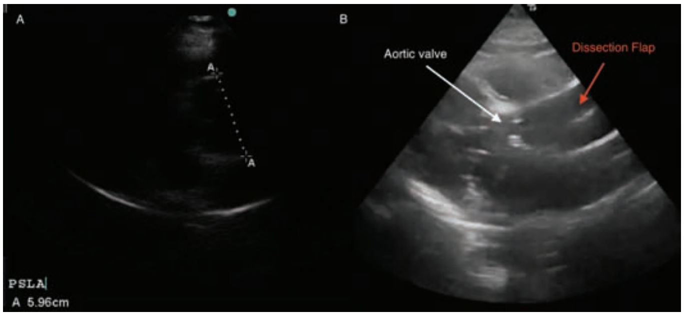


FIGURE 5.27 Parasternal long-axis views of a type A dissection. (A) Widened aortic root measuring 5.96 cm. (B) Dissection flap visualized in the ascending aorta (*red arrow*).

Pulmonary Embolus

- PE cannot be diagnosed by cardiac ultrasound. However, secondary findings of right ventricular strain can lead one to have a higher index of suspicion for PE in the right clinical context.
- Note that absence of these findings does not rule out a PE, and presence of these findings may indicate other causes of elevated right-heart pressures such as advanced pulmonary disease and pulmonary hypertension.
- Primary findings
    - Dilated RV ≤size of LV
        - Normally, the RV:LV ratio is approximately 0.6:1.
        - Best seen in apical four-chamber and PSAX views (**see VIDEO 5.3B; FIGURE 5.28**).
        - Also seen in the subxiphoid view by rotating the probe 90 degrees to the left (the patient's right).
    - "D-sign": Bowing of the interventricular septum into the LV, indicating increased right-sided pressures.
    - Paradoxical septal motion from the right to the left reflects high pulmonary artery pressure.
    - McConnell's sign is one of the most distinct and specific echocardiographic findings described in patients with a massive PE. There is a regional pattern of right ventricular dysfunction, with akinesia of the mid free wall and hypercontractility of the apical wall (though this latter point has come under some recent doubt).

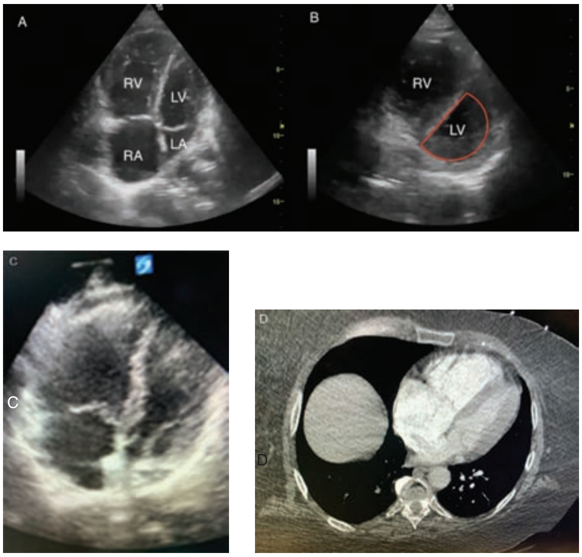


FIGURE 5.28 Cardiac views of a patient with a massive PE. (A) Apical four-chamber view. Note the increased size of the RV and RA. (B) PSAX. Note the bowing of the interventricular septum toward the LV, creating a D-shape. This is known as the *D-sign*. (C) Apical four-chamber view in a different patient with again a massive PE presented as syncope. Note again the increase in relative chamber size of the right (left of screen) chambers compared to the left. (D) CT image of same patient demonstrating an RVD/LVD greater than 1:1, which signifies elevated right pulmonary artery pressure.

LA, left atrium; LV, left ventricle; LVD, left ventricle diameter; PE, pulmonary embolism; PSAX, parasternal short axis; RA, right atrium; RV, right ventricle; RVD, right ventricle diameter.

PEARLS

- Attempt all four views on every cardiac ultrasound to gather as much information on your patient's cardiac function as you can.
- Only the subxiphoid cardiac view uses the liver as an acoustic window.
- This subxiphoid view can be difficult to obtain due to body habitus and/or overlying bowel gas; in these scenarios, try increasing the depth and firmly pressing the probe into the abdomen and angling the probe so that it is nearly parallel to the skin.
- Often, some views will be limited and your study will be incomplete. Document your limitations.
- The left lateral decubitus position brings the heart closer to the anterior chest wall and may aid visualization in difficult cases.
- Comment on all incidental abnormalities that you encounter.
- When performing cardiac ultrasound for undifferentiated hypotension, add views of the abdominal aorta, RUQ, and inferior vena cava (IVC).
  - See section of this chapter on the rapid ultrasound for shock (RUSH) exam for additional information.
- When performing cardiac ultrasound for undifferentiated dyspnea or concern for decompensated heart failure, add views of the lungs.
  - See lung section of this chapter for additional information on scanning the lungs.
- Cardiac ultrasound has a strong role in the cardiac arrest patient as any cardiac movement during resuscitation increases the chance of a return to spontaneous circulation (ROSC) by 50%; furthermore, Gaspari et al. (2016) have shown that any cardiac activity in the cardiac arrest patient predicts an overall survival of 3.8%, compared to just 0.6% with no cardiac activity.
- Given the low reliability of standard methods for determination of PEA (fingers checking a pulse) and asystole (appearance of cardiac tracing), point-of-care ultrasound (POCUS) should be universally applied to the cardiac arrest patient prior to termination of resuscitation efforts.
- Hwang et al. (2009) have shown that clinicians following the American Heart Association's hand-positioning guidelines in fact have incorrect hand position during CPR 44% of the time (compressing the left ventricular outflow tract [LVOT] and/or aorta); POCUS can help maximize proper hand positioning during active CPR.
- Many cases of massive PEs present with syncope; remember to consider PE in syncoPE.

AORTA

Indications

- Abdominal pain, back pain, flank pain, chest pain
    - ***Fifty percent of abdominal aortic aneurysm (AAA) ruptures present with back pain.***
    - ***AAA rupture carries an 80% mortality rate.***
    - ***Aortic dissection is more common than AAA and is the most common acute aortic disease.***
    - ***Every hour of delay in diagnosing an aortic dissection increases the mortality 1% to 2% as the media tearing/false lumen expands without intervention.***
- Syncope
- Hypotension
- Suspected AAA with or without rupture
- Suspected aortic dissection
- Screening ultrasound recommended for all patients ≥65 years old with history of smoking (screening)

Required Views

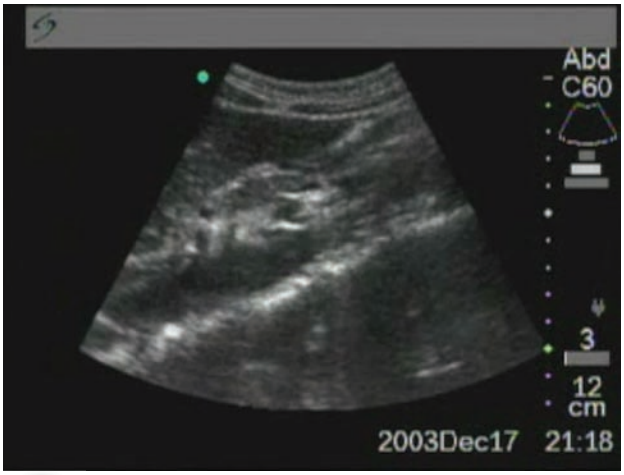
- PLAX cardiac view
    - Measure aortic root
- Transverse-sweep abdominal aorta
    - From 2 cm above the celiac trunk to the iliac bifurcation
    - May require multiple clips
- Longitudinal view of abdominal aorta
    - From 2 cm above the celiac trunk to the iliac bifurcation
    - May require multiple clips

Preparation

- Probe choice: Curvilinear (abdominal) probe for abdominal aorta
    - Phased-array (cardiac) probe for PLAX/aortic root measurement
- Patient positioning: Supine
    - Sitting or left lateral decubitus position is also acceptable for PLAX/aortic root

Procedure (**VIDEO 5.4**)

- PLAX with aortic root measurement
    - See section on PLAX
- Transverse sweep of abdominal aorta
    - Position the probe in the midline just below the xiphoid process with the probe marker pointing toward the patient's right side (**FIGURE 5.29A**).
    - Adjust depth so that the vertebral body is visualized at the bottom of your screen.
    - Identify the aorta (left of patient, right of screen), and IVC (right of patient, left of screen) just anterior to the vertebral body (**see FIGURE 5.29B**).
    - Keeping the aorta in view, sweep from the most superior view visualized caudally until the iliac bifurcation (**FIGURE 5.30**).
        - May require multiple sweeps.
    - Determine where the aorta appears largest on visual inspection, freeze at that point, and ***measure the diameter from outside wall to outside wall.***
        - Diameter greater than 3 cm is diagnostic of AAA.
        - Do not mistake the false lumen of a clot for the aortic diameter.



VIDEO 5.4 Normal aorta study.

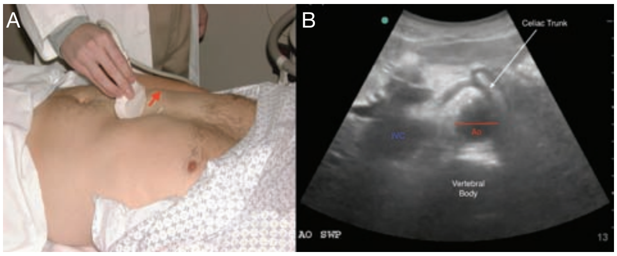


FIGURE 5.29 (A) Probe position for transverse view of abdominal aorta. (B) Transverse view of proximal aorta at the level of the celiac trunk.

Ao, aorta; IVC, inferior vena cava.

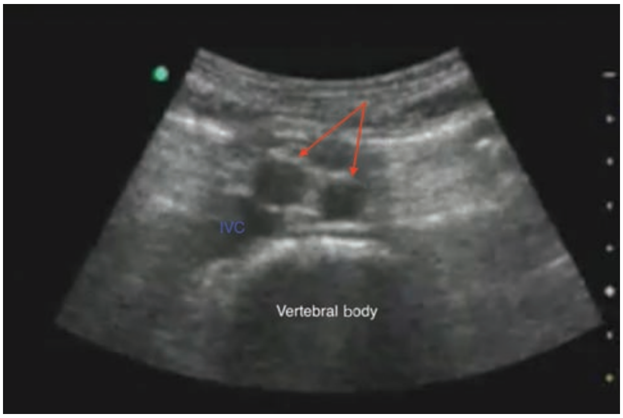


FIGURE 5.30 Transverse view of aortic bifurcation into the common iliacs (*red arrows*).

IVC, inferior vena cava.

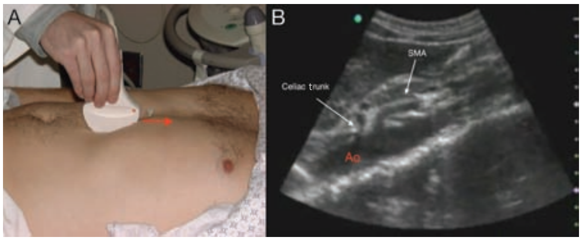


FIGURE 5.31 Probe position for longitudinal view of the abdominal aorta.

Ao, aorta; SMA, superior mesenteric artery.

- Longitudinal view of abdominal aorta
  - Position the probe in the midline just below the xiphoid process with the probe marker pointing toward the patient's head.
  - Isolate the longitudinal aorta by identifying its proximal branches—the celiac trunk and the superior mesenteric artery (SMA; **FIGURE 5.31**).
    - The SMA is a medium-caliber artery arising from the anterior aorta and turns caudal and parallel as it descends.
    - Make sure you are not mistaking the aorta for the IVC!
  - Visualize the aorta in the longitudinal axis from 2 cm above the celiac trunk to the aortic bifurcation.
  - Holding your hand still, observe the lumen of the aorta for an undulating intimal flap.
    - Pathognomonic of aortic dissection

SELECTED PATHOLOGY

Thoracic (Type A) Aortic Dissection

- Involvement of the ascending aorta
- More common than type B dissections
- Surgical emergency
- Vast majority of type A dissections involve the aortic root and are associated with aortic root widening (**see FIGURE 5.27**)
  - Less than 3.5 cm is normal
    - Argues strongly against type A dissection.
  - Greater than 4 cm is abnormal.
  - Undulating intimal flap is pathognomonic of dissection (**see FIGURE 5.27**).
  - Can also be associated with pericardial effusion.

Abdominal Aortic Dissection

- Undulating intimal flap within the aortic lumen is pathognomonic for aortic dissection.
- Visualize in both longitudinal and transverse views to confirm that it is not an artifact (**FIGURE 5.32**).

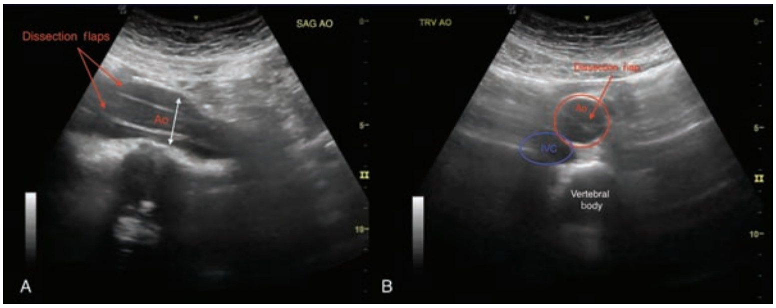

Dissection flaps
SAG AO
Ao
A
TRV AO
Dissection flap
Ao
IVC
Vertebral body
B

FIGURE 5.32 Abdominal aortic dissection. (A) Longitudinal view. Two dissection flaps are visualized within the aortic lumen. (B) Transverse view. Dissection flap is visualized within the aortic lumen.

Ao, aorta; IVC, inferior vena cava.

Abdominal Aortic Aneurysm

- Any transverse diameter greater than 3 cm is diagnostic of AAA.
- There is no reliable ultrasound finding of rupture; the goal of bedside aortic ultrasound is to identify AAA.
  - Only by combining this with clinical symptoms (and/or CT angiography) can rupture be determined.
- AAA often has an intraluminal thrombus (**FIGURE 5.33**).
  - This is an echogenic substance within the aortic lumen, usually seen on anterior and lateral walls.
- There are two types of AAA: Fusiform and saccular
  - Fusiform (**FIGURE 5.34**)
    - Most common
    - Usually projecting anteriorly and left
    - Thrombus usually on anterior wall
  - Saccular (**FIGURE 5.35**)
    - Less common
    - Attached to main vessel lumen by a mouth
    - Thrombus partially or completely fills the aneurysm

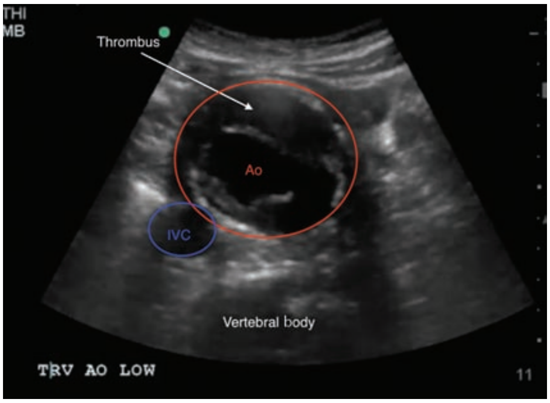

THI
MB
Thrombus
Ao
IVC
Vertebral body
TRV AO LOW
11

FIGURE 5.33 Transverse view of abdominal aortic aneurysm with intramural thrombus.

Ao, aorta; IVC, inferior vena cava.

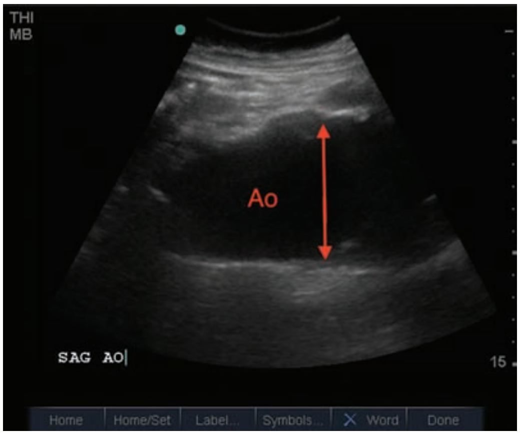

THI
MB
Ao
SAG AO
15
Home
Home/Set
Label...
Symbols...
Word
Done

FIGURE 5.34 Longitudinal view of an unruptured fusiform abdominal aneurysm measuring 7.7 cm.

Ao, aorta.

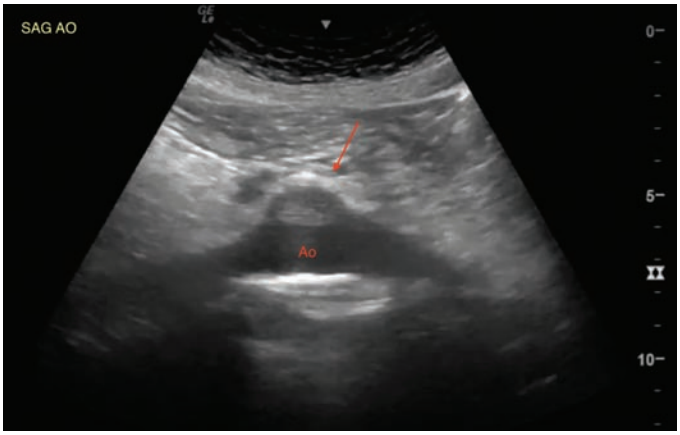

SAG AO
0
5
Ao
10

FIGURE 5.35 Longitudinal view of a saccular aneurysm (*red arrow*) measuring 3.5 cm. Note the hyperechoic thrombus within the aneurysm.

Ao, aorta.

PEARLS

- Be careful to differentiate the IVC from the abdominal aorta.
  - The aorta lies to the left of the patient (right on the screen), is pulsatile, and has a thick muscular wall.
    - Identify the celiac trunk and the SMA to ensure you have isolated the aorta correctly.
  - The IVC lies to the right of the patient (left on the screen), continues intrahepatically, and empties into the right atrium; lumen size varies with respiration.
- The abdominal aorta can be difficult to visualize due to overlying bowel gas. Steady application of gentle pressure can force gas out of the way and aid in better visualization.
- Most AAAs are asymptomatic until they rupture and because of such are diagnosed incidentally.
- Of AAAs, 85% rupture into the retroperitoneum (covered rupture). A minority rupture into the peritoneum (free rupture). Consider obtaining an RUQ view to evaluate for free fluid in the peritoneum.
  - Refer to the FAST exam section of this chapter for additional information on how to obtain this view.
- When combining transthoracic and transabdominal POCUS to assess for an intimal flap, POCUS has a sensitivity of 80% and specificity of 99% for aortic dissection.
- Computed tomography angiography (CTA) of the aorta is still the gold standard and should be obtained if your patient is stable enough.

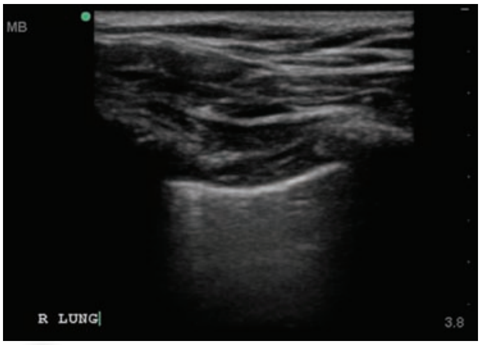
LUNGS

Indications

- Unexplained dyspnea and/or hypoxia
- Pneumothorax
- Pulmonary edema
- Pleural effusion
- Pneumonia

Required Views

- Bilateral lung apices
- Bilateral lung bases



VIDEO 5.5 Pneumothorax.

Preparation

- Probe choice
  - Linear/vascular probe is best for evaluating for pneumothorax.
  - Curvilinear/abdominal probe is best for evaluating for pulmonary edema, effusions, and consolidations.
- Patient positioning: Supine or sitting

Procedure

BILATERAL LUNG APICES (VIDEO 5.5)

- Place the probe in the longitudinal plane at the level of the second to fourth intercostal spaces in the midclavicular line (**FIGURE 5.36**).
- Make sure the probe marker is pointing toward the patient's head.
- Identify the ribs and the pleural line (**FIGURE 5.37**).
- Look for lung sliding at the pleural line (**see FIGURE 5.37**).
  - Lung sliding is best evaluated with the linear/vascular probe.
  - The movement of the visceral pleural line against the parietal pleural line during the respiratory cycle creates horizontal motion along the pleural line, often referred to as the *ants on a log* phenomenon.

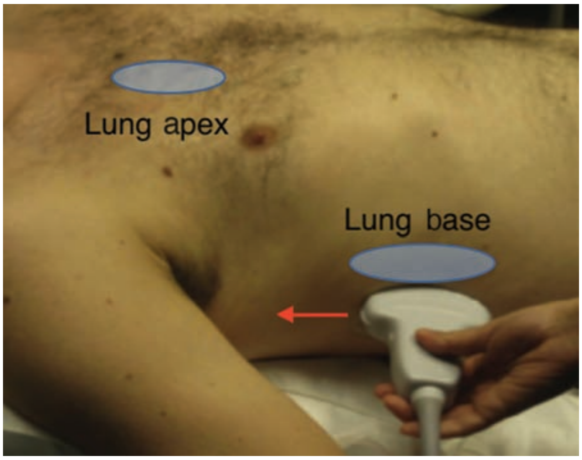


FIGURE 5.36 Probe position for views of the right lung apex and base.

- Use the "M-mode" function to confirm lung sliding. Place the M-mode cursor directly through the pleural line, perpendicular to the probe footprint (**FIGURE 5.38**).
  - A "seashore" appearance confirms proper lung sliding.
    - Note that the "ocean" represents subcutaneous tissue and the "sand" represents normal artifact secondary to the visceral and parietal pleura sliding.
- Evaluate the lung parenchyma (**FIGURE 5.39**).
  - Best evaluated by use of the curvilinear/abdominal or linear probe.
  - Normal lung is mostly aerated and cannot be seen on ultrasound. A pattern of horizontal artifacts called *A-lines* are seen in intervals of the skin surface and pleural line. ***The presence of both A-lines and lung sliding on ultrasound signifies aerated lung and effectively rules out pathology such as pneumothorax, pulmonary edema, and consolidation.***
- Perform the same evaluation on the left apex.
  - Note that you may need to move your probe up or down a rib space and/or more laterally on the chest wall to visualize the left lung parenchyma and avoid the heart.

BILATERAL LUNG BASES

- Position the probe in the midaxillary line at the level of the diaphragm with the probe marker facing the patient's head (**see FIGURE 5.36**).
- Identify the diaphragm as the hyperechoic dome-shaped structure superior to the liver and identify the lung parenchyma superior to the diaphragm (**FIGURE 5.40**).
- Evaluate the lung base for evidence of edema, effusion, or consolidation.
  - Refer to the "Selected Pathology" section for examples.

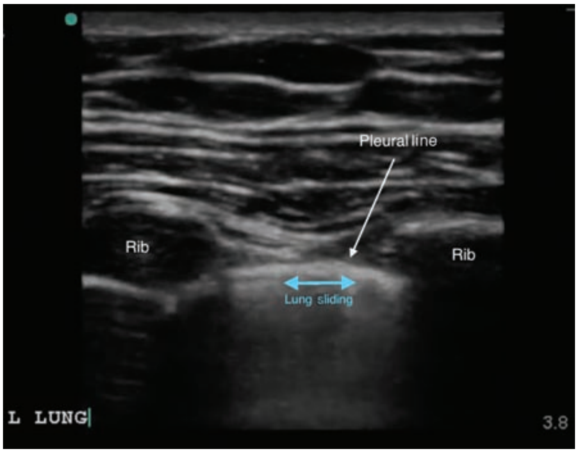


FIGURE 5.37 Sonographic appearance of the pleural line between two ribs. In a normal lung, lung sliding will be visualized in real time during the respiratory cycle.

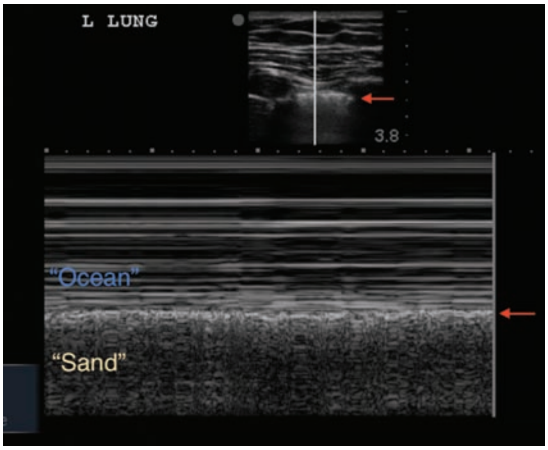


FIGURE 5.38 M-mode image demonstrating the "seashore" appearance of normal lung sliding. Red arrows demonstrate the pleural interface on both the B-mode and M-mode images.

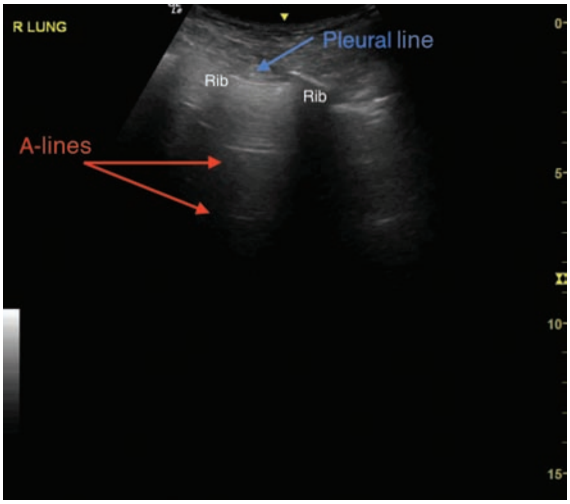


FIGURE 5.39 Sonographic appearance of normally aerated lung parenchyma. A-line artifacts (*red arrows*) appear at regular intervals below the pleural line and are parallel (*horizontal*).

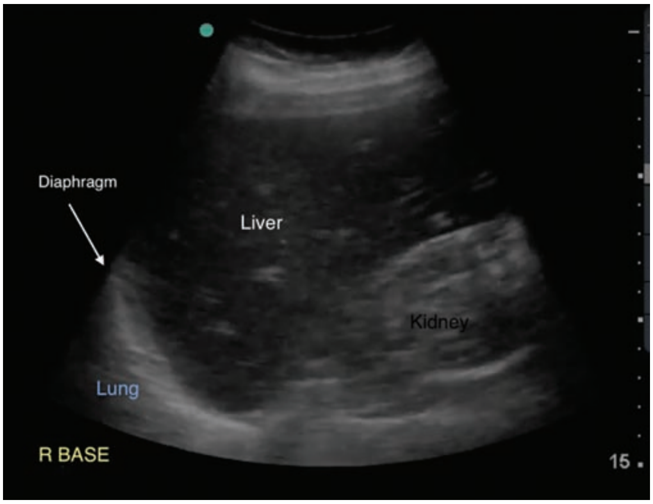


FIGURE 5.40 Longitudinal view of a normal right lung base. Lung parenchyma is visualized superior to the diaphragm.

SELECTED PATHOLOGY

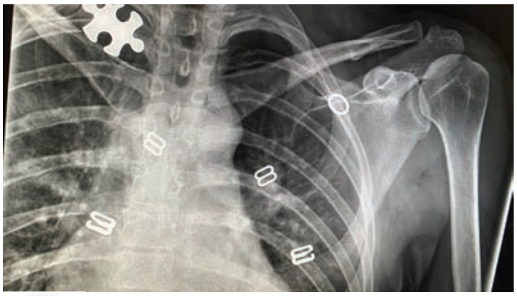
Pneumothorax

- The first reported use of ultrasound to detect pneumothorax in humans was by Wernecke, Galanski, Peters, and Hansen in 1987.
- Relative to chest x-ray (CXR), ultrasound is extremely sensitive in its ability to detect the pathological presence of air between the visceral and parietal pleural (**VIDEO 5.6; TABLE 5.2**).
- May be traumatic or atraumatic.
- B-mode sonographic finding is the absence of lung sliding during respiration.
- M-mode sonographic finding is referred to as the *stratosphere* or *barcode* sign. Instead of the "seashore" appearance created by normal lung sliding, the M-mode image looks the same above and below the pleural interface (**FIGURE 5.41**).
- Be aware that lack of lung sliding can also be seen with other pathology that interrupts normal lung movement such as pulmonary blebs, diaphragmatic paralysis, or a main-stem intubation.

TABLE 5.2 **Varying Imaging Modalities and Their Sensitivities for Detecting a Pneumothorax**

Modality	Sensitivity (%)
CXR	75
Ultrasound	95
CT	100

CXR, chest x-ray.



VIDEO 5.6 Traumatic pneumothorax initially not detected on x-ray and subsequently demonstrated via POCUS and CT.

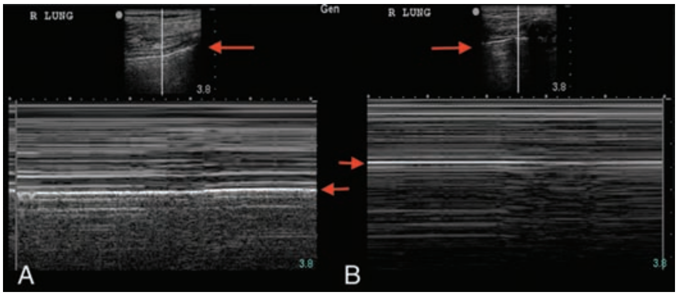


FIGURE 5.41 M-mode images of normal lung and abnormal lung sliding. (A) Normal lung sliding, demonstrated by the "seashore" sign. (B) Absence of lung sliding creates a "stratosphere" or "barcode" sign. Red arrows demonstrate the pleural interface on both the B-mode and M-mode images.

Pulmonary Edema

- Any process that causes interstitial thickening will create an artifact referred to as *B lines*.
- B-lines are vertical reverberation artifacts that originate at the pleural interface, continue to the bottom of the screen, and move with lung sliding (**FIGURE 5.42**).
- Three or more B-lines in a single view (using the curvilinear/abdominal probe) are abnormal and diagnostic of a pathological interstitial process.
- The number and intensity of B-lines increases with the degree of loss of aeration.
- *The differential diagnosis for diffuse B-lines includes pulmonary edema, fibrosis, and acute respiratory distress syndrome (ARDS).*
- *The differential diagnosis for focal B-lines includes pneumonia, pulmonary contusion, atelectasis, and malignancy.*

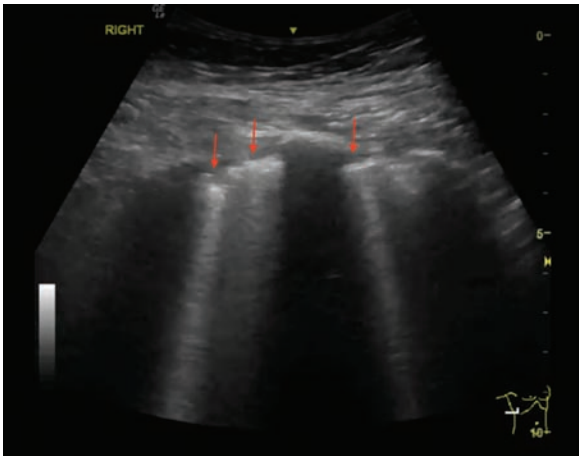


FIGURE 5.42 B-lines (*red arrows*) visualized in the right apex of a patient experiencing flash pulmonary edema.

Pleural Effusion

- Pleural effusions appear as hypoechoic (dark), homogeneous structures found in dependent areas, visible primarily at the lung bases (**FIGURE 5.43**).
- They are usually delineated by the chest wall and the diaphragm.
- There is no reliable way to differentiate an exudative effusion from a transudative effusion via ultrasound; however, free-floating echogenic material within the effusion is concerning for an exudative effusion.

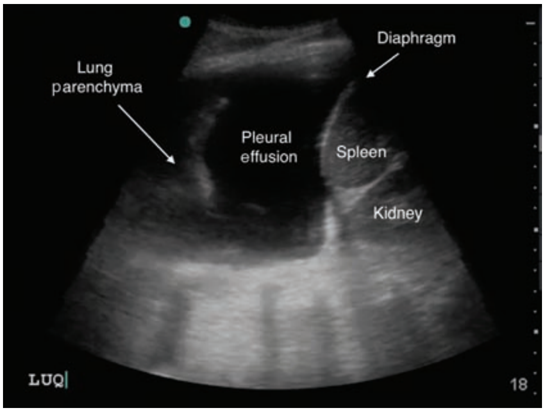


FIGURE 5.43 Large left pleural effusion in a patient with end-stage renal disease.

Pneumonia

- Consolidations appear as a dense, textured, tissue-like pattern instead of normal aerated lung (i.e., A-lines). Lung consolidations are sometimes referred to as *hepatization* as the texture of consolidated lung is similar to the texture of the liver on ultrasound (**FIGURE 5.44**).
- Consolidation should originate from the pleural line, or, if an effusion is present, will originate at the deep boundary of the effusion.
- Air bronchograms may also be seen within a lung consolidation and differentiate pneumonia from atelectasis. ***Air bronchograms are bright, hyperechoic foci within the consolidated lung that represent air traveling though the consolidation*** (**see FIGURE 5.44**). In the case of atelectasis, peripheral airways are collapsed and thus air bronchograms will not be seen.

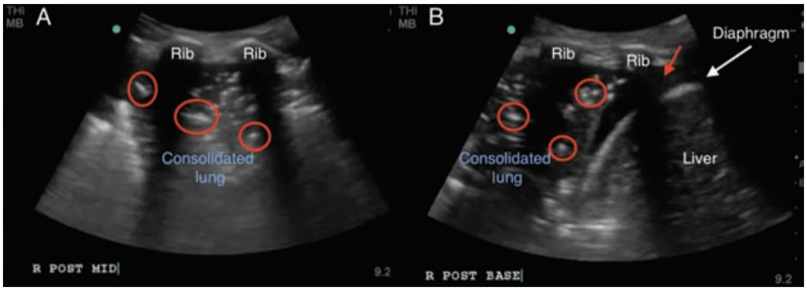


FIGURE 5.44 R lower lobe consolidation in a patient with pneumonia. (A) Consolidation with multiple air bronchograms (*red circles*). (B) Lung consolidation at the right base with a small effusion (*red arrow*). Note the similarity in texture between the consolidate lung parenchyma and the liver.

PEARLS

- Lung ultrasound is especially useful in the undifferentiated wheezing patient. B-lines are suggestive of pulmonary edema, whereas A-lines signify normally aerated lung and may suggest obstructive lung disease.
- When using ultrasound to differentiate between congestive heart failure (CHF) and chronic obstructive pulmonary disease (COPD), this examination has been shown to have a sensitivity of 100% and a specificity of 92%.
- By performing lung ultrasound immediately upon a patient's arrival to the ED, the clinician can obtain quick and accurate insight into whether a patient would benefit from albuterol or nitroglycerin.
- In the acutely dyspneic patient, combining lung ultrasound with focused echocardiogram and sonographic IVC assessment provides additional information to support the diagnosis.
- Two ultrasound findings ***of aerated lungs*** are "A-lines" and "lung sliding."
- "A-lines," which stands for *air lines*, are seen in any aerated structure. A-lines may be seen with pneumothorax; lung-sliding will not be seen with pneumothorax.
- Lung sliding is best evaluated using the linear/vascular probe.
- Sliding is best evaluated at the lung apex in a supine patient.

- Remember the other causes for absence of lung sliding such as blebs, diaphragmatic paralysis, or a mainstem intubation.
- Lung parenchyma is best evaluated using the curvilinear/abdominal probe.
- B-lines are a pathologic artifact that represents an interstitial process in the lung parenchyma, which may be diffuse or localized.
- B-lines are pathologic (interstitial edema), whereas comet-tail artifacts are normal.
- After identifying the pleural interface in the longitudinal plane, consider changing to the transverse view to better evaluate the lung parenchyma.
- Lateral decubitus positions can be utilized to help identify smaller effusions.
- When the lung bases are difficult to visualize, move the probe more posteriorly and angle it between the rib spaces. Ask your patient to take a deep breath to move the diaphragm inferiorly below the ribcage.
- The sensitivity of detecting a pneumothorax with POCUS approaches 95% (CXR's sensitivity is 85%) and the fact that it can be done at the bedside in seconds makes this a skill all acute care clinicians must master.
- CT remains the gold standard for diagnosing pneumothoraces.

DEEP VENOUS THROMBOSIS

Indications

- Suspected deep venous thrombosis (DVT) or pulmonary embolus (PE)

MB
R FEM
3.8
Home
Home/Set
Label...
Symbols...
Word
Done

VIDEO 5.7 Normal DVT study.

Required Views

- Common femoral veins (CFV) with and without manual compression
- Popliteal veins with and without manual compression
- Contralateral leg views may be obtained as well but are likely unnecessary in ambulatory patients

Preparation

- Probe choice: Linear/vascular probe
  - Curvilinear/abdominal probe may be required in obese patients
- Patient positioning: Supine or reverse Trendelenburg
  - Popliteal view will require patient cooperation and/or lateral decubitus position to access the popliteal fossa.

Procedure

COMMON FEMORAL VEINS (**VIDEO 5.7**)

- Position the probe at or just below the inguinal ligament in the transverse plane with the probe facing toward the patient's right side (**FIGURE 5.45**).
- Identify the common femoral vessels. The CFV will lie medial to the artery.
- Image the area from the saphenous vein branch until the CFV splits into the femoral and deep femoral veins. The entire region is about 7 cm long. Apply manual compression every 1 to 2 cm along this region. Be sure to compress until the vein walls touch (**see FIGURE 5.45**).
  - Failure of the vein to collapse completely suggests a DVT. Apply enough pressure to make the arterial walls collapse if you are uncertain.

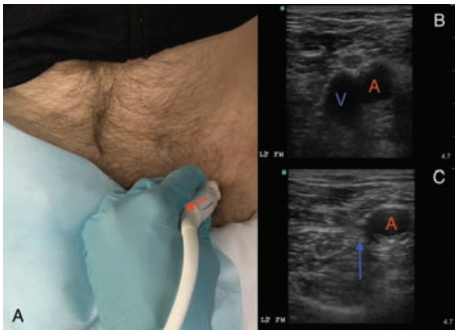


FIGURE 5.45 (A) Probe position for left common femoral vein evaluation. (B) Normal left common femoral vein without compression. (C) With compression. Notice complete collapse of the vein lumen (*blue arrow*).

A, artery; V, vein.

BILATERAL POPLITEAL VEINS

- Have the patient flex at the knee approximately 10 degrees or lie in the lateral decubitus position to access the popliteal fossa. Position the probe in the transverse plane with the probe indicator facing the patient's right side.
- Identify the popliteal vessels. ***The popliteal vein lies superficial and lateral to the popliteal artery***. Adjust depth to visualize the femur posterior to the popliteal vessels (**FIGURE 5.46**).
- Image the entire popliteal fossa from the superior fossa to the trifurcation of the popliteal vein. The entire region is about 5 cm long. Apply manual compression every 1 cm of this region. Be sure to compress until the vein walls touch.
    - Failure of the vein to collapse completely suggests a DVT. Apply enough pressure to make the arterial walls collapse if you are uncertain.

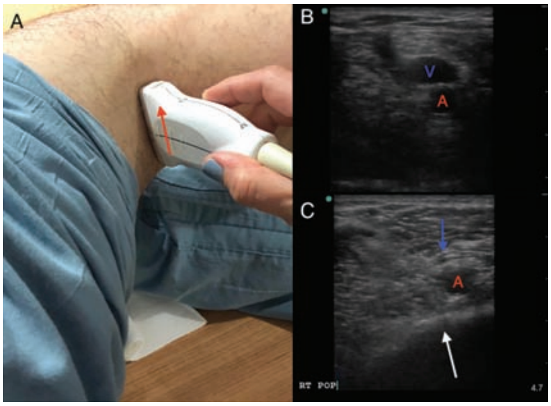


FIGURE 5.46 Normal right popliteal vein. (A) Probe position. (B) Without compression. (C) With compression. Notice complete collapse of the vein lumen (*blue arrow*). The femur is identified by the white arrow.

A, artery; V, vein.

SELECTED PATHOLOGY

Common Femoral DVT

- CFV DVTs may be diagnosed indirectly by visualizing a noncompressible vein and/or directly by visualizing an echogenic thrombus within the lumen of a noncompressible vein (**FIGURE 5.47**).

Popliteal DVT

- Popliteal DVT may be diagnosed indirectly by visualizing a noncompressible vein and/or by directly visualizing an echogenic thrombus in the lumen of a noncompressible vein (**FIGURE 5.48**).

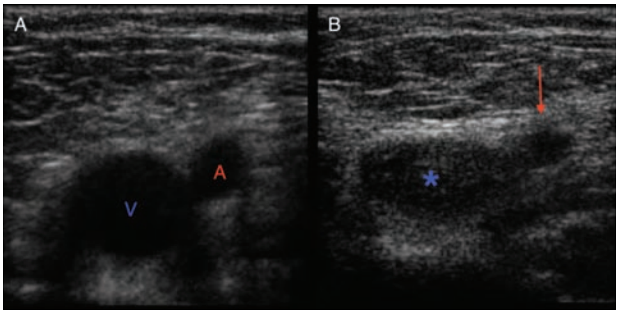


FIGURE 5.47 Left common femoral vein DVT. (A) Without compression. (B) With compression. Note the collapse of the arterial walls (*red arrow*) as well as the echogenic thrombus within the vein lumen (*blue asterisk*).

A, artery; DVT, deep venous thrombosis; V, vein.

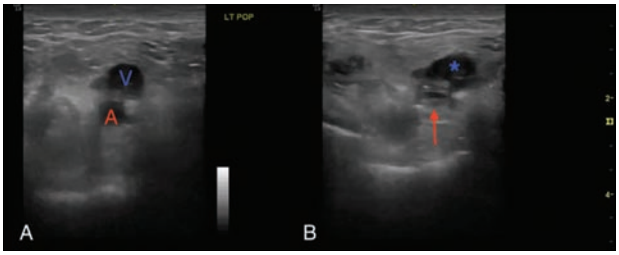


FIGURE 5.48 Left popliteal DVT. (A) Without compression. (B) With compression. Note the collapse of the arterial walls (*red arrow*) as well as the echogenic thrombus within the vein lumen (*blue asterisk*). The femur is identified by the white arrows.

A, artery; DVT, deep venous thrombosis; V, vein.

PEARLS

- Position the patient so the leg of interest is dependent, thereby engorging veins and allowing for easier visualization.
- Remember anatomy. ***Deep veins are always paired with an artery***. Do not let superficial vessels or lymph nodes fool you, especially on obese patients.
- Using the curvilinear/abdominal probe may not provide enough pressure to collapse the vein unless it is centered directly over the vein.
- Remember that the iliac vessels are not visualized in the two-point compression DVT ultrasound. If you have a high clinical suspicion, you may need additional imaging to rule out an iliac DVT.

UNDIFFERENTIATED HYPOTENSION: THE RUSH EXAM

The RUSH (rapid ultrasound for shock and hypotension) exam is a relatively new protocol developed to utilize ultrasound to rapidly identify causes of undifferentiated hypotension. The RUSH protocol involves viewing the heart, aorta, IVC, and abdomen with optional additional views of the lungs and deep veins of the lower extremities (**FIGURE 5.49**). It is important to remember that shock results in impaired tissue perfusion, cellular hypoxia, and cellular death and depend on the severity and duration of inadequate organ perfusion and tissue oxygenation. The days of simply and blindly infusing crystalloid into such patients have been replaced with determining the etiology of such a low-flow state and tailoring interventions accordingly. In a large meta-analysis, the RUSH exam was shown to have a sensitivity and specificity of 87% and 98%, respectively, in regard to diagnosing the correct etiology of shock. This is a critical POCUS skill set that cannot be overemphasized and underscores the utility of this bedside modality; this section reviews the four fundamental views that comprise the RUSH exam.

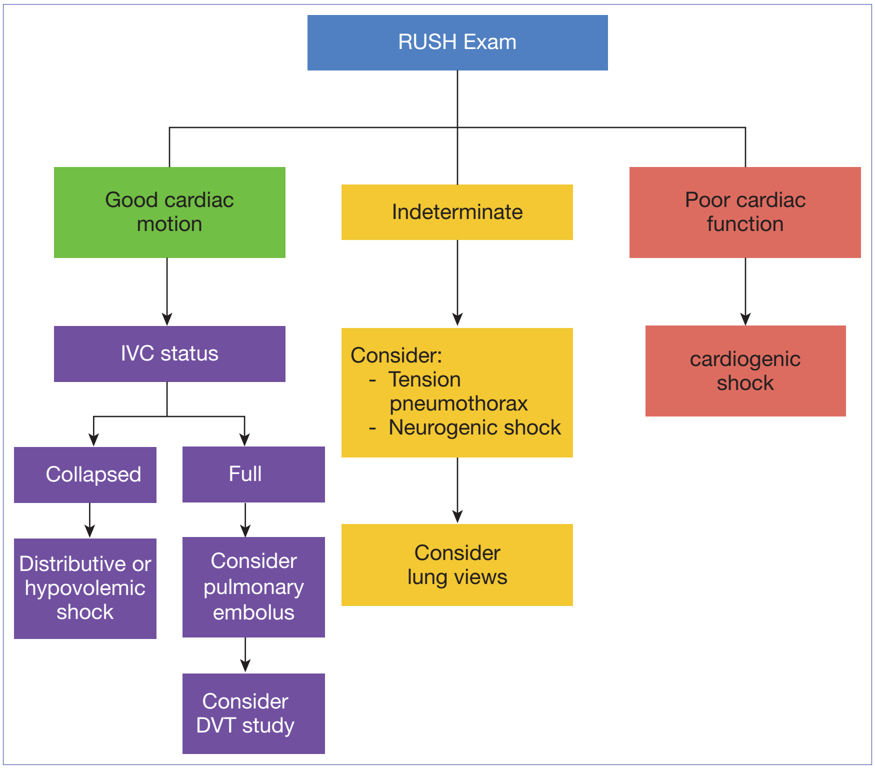

RUSH Exam
Good cardiac motion
Indeterminate
Poor cardiac function
IVC status
Consider:
- Tension pneumothorax
- Neurogenic shock
cardiogenic shock
Collapsed
Full
Distributive or hypovolemic shock
Consider pulmonary embolus
Consider lung views
Consider DVT study

FIGURE 5.49 RUSH algorithm. Rapidly assess for cardiac tamponade, abdominal free fluid, and aortic pathology, and then proceed down this pathway.

DVT, deep venous thrombosis; IVC, inferior vena cava; RUSH, rapid ultrasound for shock and hypotension.

Indications

- Undifferentiated hypotension
- Essentially evaluates the:
  - Pump (Heart)
  - Pipes (Aorta)
  - Tank (IVC/peritoneal cavity)

Required Views

- Subxiphoid cardiac view ***(Pump)***
- Inspiratory and expiratory measurements of IVC diameter ***(Tank)***
- Abdominal aorta ***(Pipe)***
- RUQ/Morison's pouch ***(Pipe)***

Preparation

- Probe choice
  - Curvilinear/abdominal probe
- Patient positioning: Supine

Procedure

SUBXIPHOID CARDIAC VIEW

- Place the probe in the transverse plane just inferior to the xiphoid process with the probe marker toward the patient's right side (**FIGURE 5.50A**).
- Grip the probe from the top and create a shallow angle, nearly parallel to the patient's skin.
- Apply gentle downward pressure, looking "up and under" the xiphoid process toward the patient's thorax.
- Use the liver as an acoustic window and adjust depth so the heart appears below the liver.
- *Adjust gain so blood in ventricles appears black.*
- Be sure to visualize both the superior and inferior pericardial borders (**FIGURE 5.50B**).
- Key findings:
  - Assess for presence of pericardial effusion/tamponade.
  - Assess global heart function.

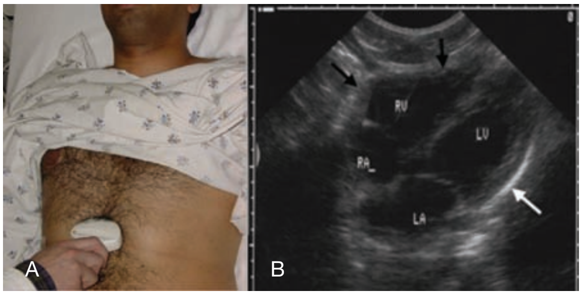


FIGURE 5.50 Normal subxiphoid view. (A) Photograph showing probe placement. (B) The superior pericardial border is identified by the white arrow and the inferior pericardial border is identified by the black arrows. Note that because the heart is being viewed from below, the inferior border is visualized at the top of the screen, closest to the probe.

LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

INFERIOR VENA CAVA VIEWS

- Position the probe in the midline just below the xiphoid process with the probe marker pointing toward the patient's head (**FIGURE 5.51A**).
- Identify the IVC by visualizing the hepatic veins draining into the proximal IVC and the cavo-atrial junction.
- The IVC lies to the right of the aorta, is not pulsatile, and exhibits respiratory variation.
- Observe the respiratory variation in IVC diameter (**FIGURES 5.51B** and **5.51C**). In a normal, nonmechanically ventilated patient, the IVC will collapse when intrathoracic pressure decreases during inspiration. Note that the opposite will happen in a mechanically ventilated patient as intrathoracic pressure is *increased* during inspiration due to the positive inspiratory pressure.

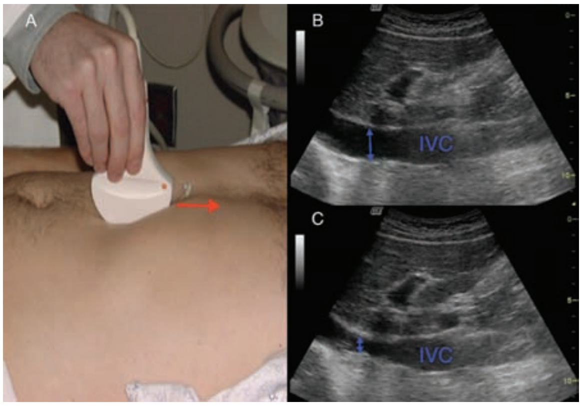


FIGURE 5.51 (A) Probe placement for longitudinal IVC view. (B) IVC expiratory diameter. (C) IVC inspiratory diameter.

IVC, inferior vena cava.

- Measure both the widest and narrowest diameter of the IVC visualized during the respiratory cycle.
  - Less than 1.5 cm or 100% collapse = low central venous pressure (CVP)
  - 1.5 to 2.5 cm and less than 50% collapse = normal CVP
  - Greater than 2.5 cm and no collapse = high CVP

ABDOMINAL AORTA

- Obtain transverse and longitudinal views of the abdominal aorta to evaluate for AAA or dissection (**FIGURE 5.52**).
- Refer to the aorta section of this chapter for how to obtain these views.

RIGHT UPPER QUADRANT/MORISON'S POUCH

- Obtain a longitudinal image with probe marker facing the patient's head (**FIGURE 5.53A**).
- Identify the hepatorenal fossa, a potential space between the liver and the right kidney.
- Sweep the entire area from right to left (posterior to anterior).
- Be sure to view the posterior pleural space, diaphragm, liver, lower pole of right kidney, and cephalad colic gutter.
- Blood will appear as dark (hypoechoic) fluid collecting primarily in Morison's pouch (**FIGURE 5.53B**).

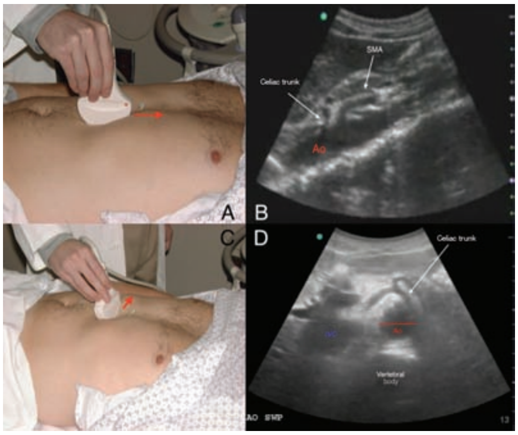


FIGURE 5.52 Probe position for longitudinal (A and B) and transverse (C and D) views of the abdominal aorta.

Ao, aorta; IVC, inferior vena cava; SMA, superior mesenteric artery.

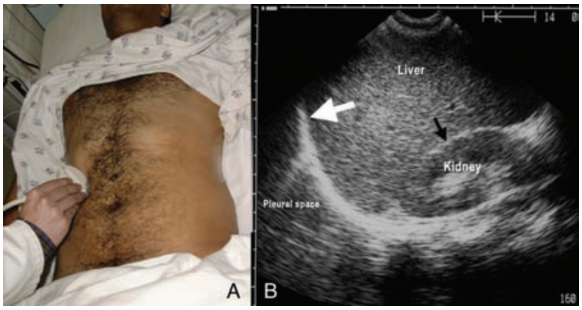


FIGURE 5.53 (A) Probe position for RUQ view. (B) Normal RUQ view. The black arrow identifies Morison's pouch, the potential space between the liver and the right kidney. The white arrow identifies the diaphragm.

RUQ, right upper quadrant.

SELECTED PATHOLOGY

Hypovolemic Shock

- Hypovolemic shock is due to hemorrhage or hypovolemia from sensible or insensible losses.
  - The differential diagnosis for hemorrhagic shock includes:
    - Traumatic: Hemothorax, hemoperitoneum, retroperitoneal hemorrhage, external hemorrhage
    - Atraumatic: Gastrointestinal (GI) bleed, ruptured AAA, ruptured ectopic, postpartum hemorrhage, hemorrhagic pancreatitis
  - The differential diagnosis for hypovolemic shock includes:
    - GI loss: Vomiting, diarrhea
    - Severe burn injuries
    - Genitourinary (GU) loss: Overdiuresis, post-obstructive

- Possible ultrasound findings for hypovolemic shock include:
  - Cardiac: Underfilled ventricles, hyperdynamic global function
  - IVC: Highly collapsible, greater than 50% collapsibility
  - Aorta: Dissection or aneurysm (**see FIGURE 5.54A**)
  - RUQ: Free peritoneal fluid (**FIGURE 5.54B**)

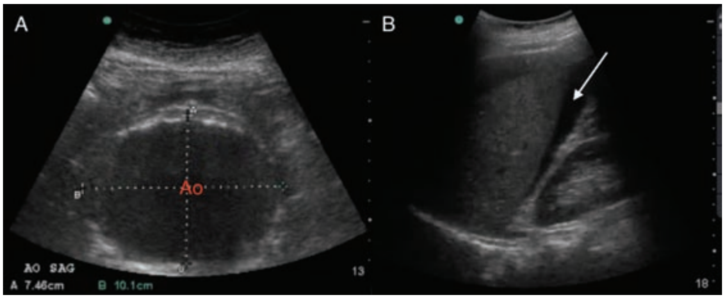


FIGURE 5.54 (A) Transverse aorta view in a patient in hypovolemic shock from a ruptured aortic aneurysm. The transverse aorta measures 7.46 cm by 10.1 cm. (B) RUQ/Morison's pouch view in the same patient. Note the anechoic free fluid in the hepatorenal space (*white arrow*).

Ao, aorta; RUQ, right upper quadrant.

Cardiogenic Shock

- Hemodynamic shock due to left ventricular failure.
- The differential diagnosis for cardiogenic shock includes:
  - Systolic failure: Ischemia/infarction, myocarditis, beta-blocker overdose
  - Valvular insufficiency: Endocarditis, papillary muscle rupture, aortic dissection, prosthetic valve thrombosis
- Possible ultrasound findings in cardiogenic shock:
  - Cardiac: Dilated, poor global function, hypodynamic (**FIGURE 5.55A**)
  - IVC: Distended, greater than 2.5 cm, or 0% collapsibility (**see FIGURE 5.55B**)
  - Aorta: Dissection
    - **See FIGURE 5.27**
  - Lungs: Pleural effusions, B-lines (pulmonary edema)
    - **See FIGURES 5.42** and **5.43**

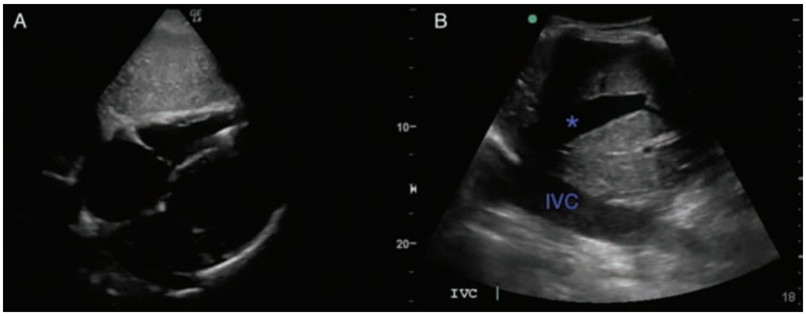


FIGURE 5.55 (A) Subxiphoid view of the heart in a patient with cardiogenic shock from decompensated heart failure. (B) IVC view in the same patient. Note a distended hepatic vein (*) draining into a distended IVC.

IVC, inferior vena cava.

Distributive Shock

- Hemodynamic shock due to vasodilation.
- The differential diagnosis for distributive shock includes:
  - Severe systemic inflammation: Sepsis, pancreatitis, anaphylaxis, postarrest
  - Metabolic derangements: Adrenal crisis, thyroid storm
  - Neurogenic shock: Severe spinal trauma
- Possible ultrasound findings in distributive shock:
  - Cardiac: Hyperdynamic global function
  - IVC: Highly collapsible, greater than 50% collapsibility
  - RUQ: Free intraperitoneal fluid (ascites)
    - **See FIGURE 5.54B**
  - Lungs: B-lines, pleural effusion (pulmonary edema)
    - **See FIGURES 5.42** and **5.43**

Obstructive Shock

- Hemodynamic shock due to physical obstruction of the cardiovascular system.
- The differential diagnosis for distributive shock includes tension pneumothorax, PE, and cardiac tamponade.
- Possible ultrasound findings in obstructive shock:
  - Cardiac
    - Tamponade: Pericardial effusion (**see FIGURE 5.25**)
    - PE: Dilated right heart chambers, D-sign (**see FIGURE 5.28**)
  - IVC: Distended, greater than 2.5 cm, or 0% collapsibility (**see FIGURE 5.55B**)
  - Lungs
    - Pneumothorax: Absent lung sliding (**see FIGURE 5.41**)
  - DVT: Positive (**see FIGURES 5.47** and **5.48**)
    - *Absence of a DVT does not rule out a PE as 50% of patients with a confirmed PE do not exhibit DVT upon testing.*

PEARLS

- Remember that this is a rapid assessment in a potentially unstable patient. It should take no more than 5 minutes to obtain and interpret the fundamental views. Do not delay other critical interventions.
- Consider obtaining lung views to assess for pneumothorax as a cause of obstructive shock. Refer to the lung section of this chapter for how to obtain these views.
- Consider obtaining a DVT study if there is a concern for PE as a cause of obstructive shock. Refer to the DVT section of this chapter for how to obtain these views.

BILIARY

Indications

- RUQ pain, nausea, and vomiting
- Suspected cholecystitis or biliary colic

Required Views

- Longitudinal gallbladder view
- Transverse gallbladder view
- Gallbladder wall measurement
- Portal triad view with common bile duct (CBD) measurement if needed

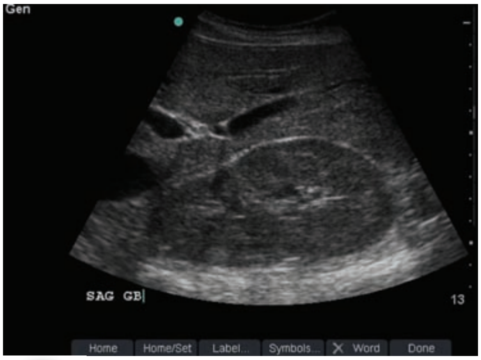
Preparation

- Probe choice: Curvilinear/abdominal probe
- Patient positioning: Supine or left lateral decubitus

Procedure

LONGITUDINAL GALLBLADDER VIEW (VIDEO 5.8)

- Place your probe in the midline just below the xiphoid process in the longitudinal plane with the probe marker pointing toward the patient's head (**FIGURE 5.56A**).
- Move laterally toward the patient's right side, keeping the liver edge in view until the gallbladder comes into view.
- Identify the gallbladder as a fluid-filled, oblong structure with an echogenic wall.
- Rotate the probe so that the entire long axis of the gallbladder is visualized and sweep from right to left, capturing the entire gallbladder in its long axis (**FIGURE 5.56B**).



VIDEO 5.8 Normal GB study.

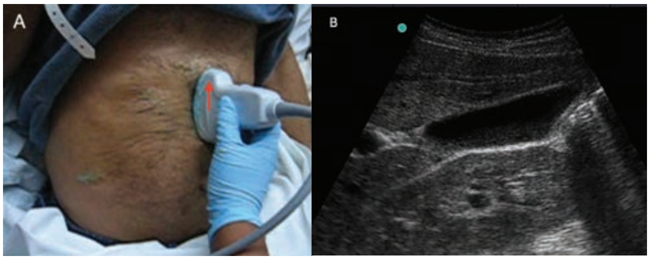


FIGURE 5.56 (A) Initial probe placement for gallbladder sonography. (B) Longitudinal view of a normal gallbladder.

TRANSVERSE GALLBLADDER VIEW

- After visualizing the gallbladder in the longitudinal axis and keeping the gallbladder in view, rotate the probe 90 degrees counterclockwise to visualize the gallbladder in the transverse or short-axis view.
- Sweep from cranial to caudal, visualizing the gallbladder fundus superiorly and the gallbladder neck inferiorly (**FIGURE 5.57**).

GALLBLADDER WALL MEASUREMENT

- In the transverse plane, zoom in and measure the thickness of the ***anterior*** gallbladder wall (outer wall to outer wall). Measurement over 3 mm is abnormally thickened (**FIGURE 5.58**).
  - Note that in a postprandial state, the gallbladder is contracted and the wall may appear abnormally thickened.
  - Anterior wall measurement is preferred as posterior enhancement can cause increased echogenicity of the posterior wall and distort measurement.

COMMON BILE DUCT MEASUREMENT

- Return to the longitudinal plane and locate the portal triad, which is often found following the gallbladder neck longitudinally along the main lobar fissure toward the portal vein.
- The sonographic portal triad view is often referred to as the *Mickey Mouse sign*; the portal vein is Mickey's face and the CBD and hepatic artery are Mickey's ears (**FIGURE 5.59**).
- ***Use color Doppler to distinguish the CBD (lack of flow) from the hepatic artery (pulsatile flow)***. Measure the CBD.
  - CBD less than 4.5 mm or less than 1 mm per decade of life is normal.

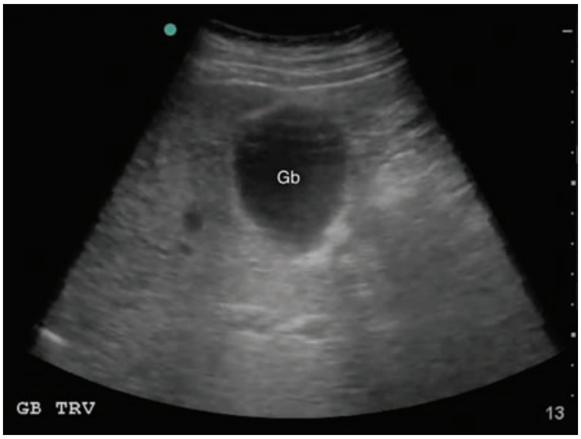


FIGURE 5.57 Transverse view of a normal gallbladder. Gb, gallbladder; TRV, transverse.

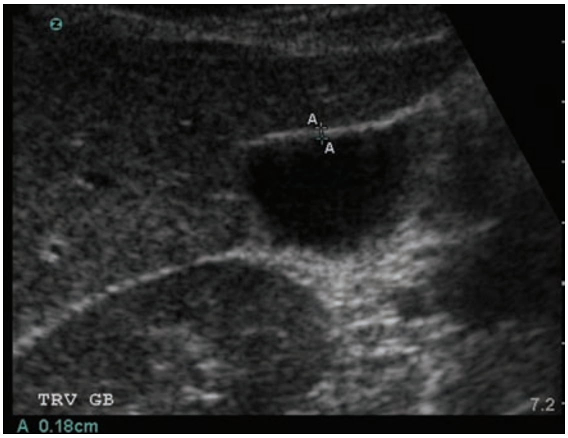


FIGURE 5.58 A normal gallbladder wall measuring 1.8 mm.

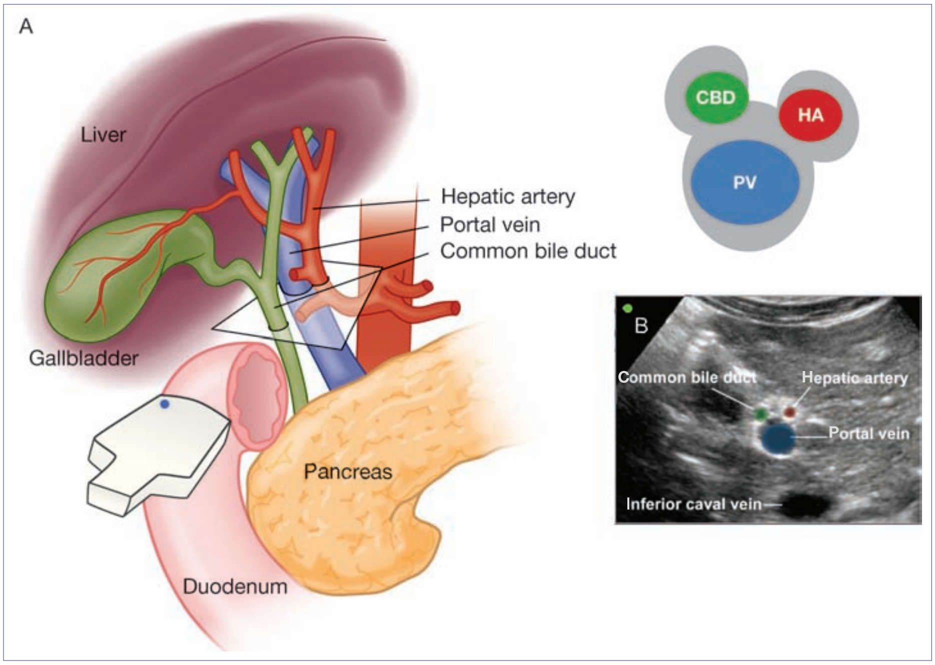


FIGURE 5.59 Portal triad anatomy. (A) Ultrasound of the portal triad with corresponding "Mickey Mouse sign" schematic. (B) Sonographic portal triad view with CBD measuring 4.4 mm. Note the lack of color doppler flow through the CBD.

CBD, common bile duct; HA, hepatic artery; PV, portal vein.

SELECTED PATHOLOGY

Cholelithiasis

- Cholelithiasis is diagnosed by the presence of gallstones without other evidence of acute cholecystitis.
- Gallstones will appear within the gallbladder lumen as brightly echogenic foci with dense posterior acoustic shadowing that is gravity-dependent (**FIGURE 5.60**).

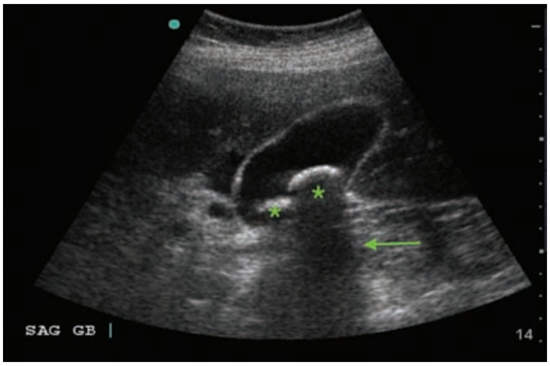


FIGURE 5.60 Cholelithiasis. Two gallstones are visualized within the gallbladder lumen in this longitudinal view (*). Note the dense posterior shadowing (*arrow*).

Cholecystitis

- Cholecystitis is gallbladder inflammation most often caused by an impacted gallstone in the gallbladder neck.
- Sonographic findings in cholecystitis include gallstones, thickened gallbladder wall (> 3 mm), and pericholecystic fluid (**FIGURE 5.61**).
- *According to one study by Ralls et al. (1985), sonographic findings of gallstones plus any one of the following criteria yielded greater than 90% positive predictive value for acute cholecystitis:*
    - *Sonographic Murphy's sign*
    - *Wall thickness greater than 3 mm*
    - *Pericholecystic fluid*

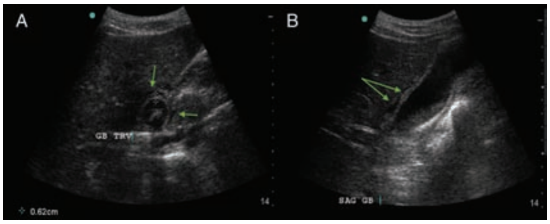


FIGURE 5.61 Acute cholecystitis. (A) Transverse gallbladder view with thickened wall measuring 6.2 mm. (B) Longitudinal gallbladder view. Green arrows indicate hypoechoic pericholecystic fluid outside the gallbladder wall.

Choledocholithiasis

- Choledocholithiasis is caused by an impacted stone within the CBD. *It is often difficult to directly visualize a CBD stone on ultrasound, but an enlarged CBD can be a secondary finding in the right clinical context* (**FIGURE 5.62**).

- It is important to remember that CBD enlargement can be caused by many obstructive processes, including malignancy.
- The CBD enlarges with time. Any CBD measurement under 4.5 mm is normal. ***Add an additional 1 mm of accepted CBD size for every decade in adults over age 40***.

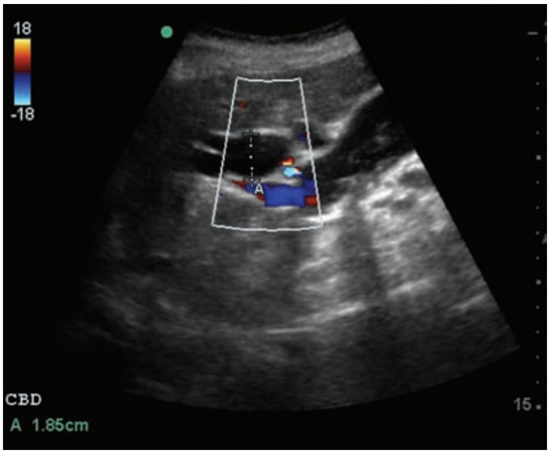


FIGURE 5.62 Choledocholithiasis in a patient with a CBD measuring 18.5 mm. Note the lack of color flow distinguishing the CBD from the rest of the portal triad.

CBD, common bile duct.

PEARLS

- Having the patient take a deep breath and holding it often causes the liver/gallbladder to descend and allows for better visualization.
- While performing this exam, note the presence or absence of a sonographic Murphy's sign, which is a point of maximal tenderness over the gallbladder. ***Presence of Murphy's sign increases the likelihood of cholecystitis***.
- When unable to visualize the gallbladder sonographically, it is usually for one of three reasons:
  1. The gallbladder has been surgically removed.
  2. The gallbladder is contracted due to a postprandial state.
  3. The gallbladder is filled with stones, thus creating a wall-echo-shadow (WES) sign (**FIGURE 5.63**).
- Do not mistake a fluid-filled duodenum for the gallbladder. The duodenum has a hypoechoic (dark) wall, and will demonstrate peristalsis.
- Be aware that gallbladder wall thickening may be caused by numerous other disease states other than cholecystitis:
  - Ascites
  - CHF
  - Nephrotic syndrome
  - HIV/AIDS
  - Renal failure
  - Postprandial state (contracted gallbladder)
- Polyps may be mistaken for gallstones. The former are nonmobile, do not shadow, and are adjacent and attached to the inner gallbladder wall. Many times, polyps are not in the dependent portion of the gallbladder.

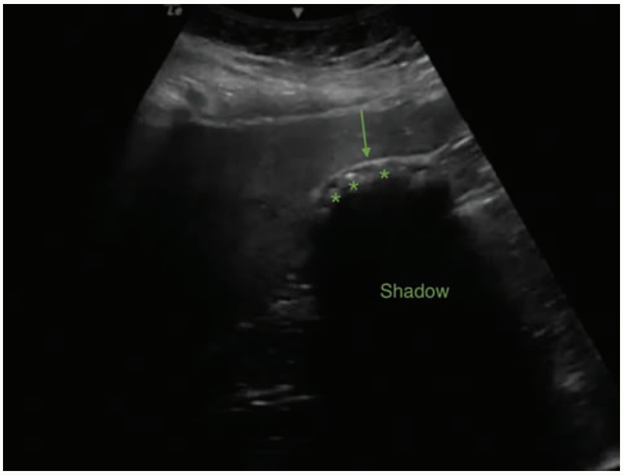


FIGURE 5.63 Wall-echo-shadow sign. Note the hyperechoic wall (*arrow*), a thin layer of hypoechoic bile, and the echogenic surface of multiple gallstones (*) casting a dense posterior shadow.

KIDNEY

Indications

- Flank pain, hematuria; suspected nephrolithiasis
- Febrile urinary tract infection (UTI); pyelonephritis
- New-onset acute renal failure; obstructive uropathy

Required Views

- Longitudinal and transverse views of right kidney
- Longitudinal and transverse views of left kidney
- Bladder view +/– ureteral jets

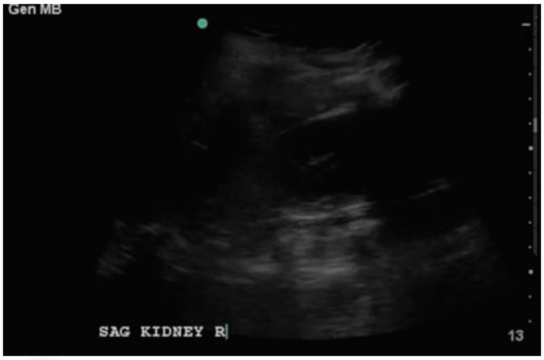
Preparation

- Probe choice: Curvilinear/abdominal probe
- Patient positioning: Supine or left lateral decubitus

Procedure

RIGHT KIDNEY VIEWS (**VIDEO 5.9**)

- Position the probe in the right midaxillary line with the probe indicator facing toward the patient's head.
- Identify the hepatorenal interface (Morison's pouch), and move the probe slightly inferiorly to center the screen on the kidney (**FIGURE 5.64**).
- Sweep the entire kidney from right to left (posterior to anterior).
- Identify the renal architecture (**see FIGURE 5.64**):
  - *The renal capsule is thin and brightly echogenic.*
  - The renal parenchyma has two sonographically distinct zones:
    - The outer *renal cortex* is hypoechoic.
    - The inner *renal sinuses* are brightly echogenic.
    - When the kidney is well-hydrated or there is a downstream obstruction, the renal calyces and pelvis will appear anechoic and dilated. This is *hydronephrosis*.
- After sweeping through the longitudinal kidney, obtain a transverse view by rotating the probe 90 degrees counterclockwise so that the probe indicator is facing the patient's right side (**FIGURE 5.65**).
- Again, identify the characteristic renal architecture and sweep the entire kidney from cranial to caudal.



VIDEO 5.9 Normal renal study.

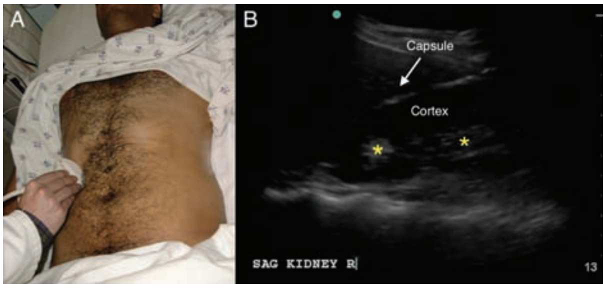


FIGURE 5.64 Longitudinal view of a normal right kidney. (A) Probe position. (B) Normal sonographic renal anatomy. Note the brightly echogenic renal capsule (*arrow*), the hypoechoic outer cortex, and hyperechoic inner renal sinuses (*yellow asterisks*).

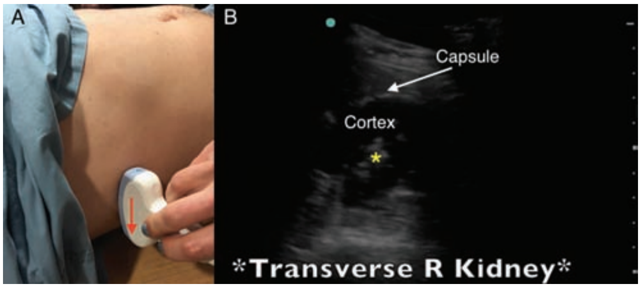


FIGURE 5.65 Transverse view of a normal right kidney. (A) Probe position. (B) Normal sonographic renal anatomy. Note the brightly echogenic renal capsule (*arrow*), the hypoechoic outer cortex, and hyperechoic inner renal sinuses (*yellow asterisks*).

LEFT KIDNEY VIEWS

- Position the probe in the left midaxillary line with the probe indicator facing toward the patient's head.
- Identify the splenorenal interface and move the probe slightly inferiorly to center the screen on the kidney (**FIGURE 5.66**).
- ***The left kidney can be more difficult to visualize as the spleen does not provide as large an acoustic window as the liver on the right; a right lateral decubitus position may aid in visualization of the left kidney***.
- Sweep the entire kidney from right to left (anterior to posterior), identifying the characteristic architecture and looking for evidence of hydronephrosis.
- After sweeping through the longitudinal kidney, obtain a transverse view by rotating the probe 90 degrees counterclockwise so that the probe indicator is facing the patient's right side (**FIGURE 5.67**).
- Again, identify the characteristic renal architecture and sweep the entire kidney from cranial to caudal.

BLADDER VIEWS

- Position the probe in the transverse plane just above the pubic symphysis with the probe indicator toward the patient's right (**FIGURE 5.68A**).
- Change the ultrasound machine's video settings to "retro" and add color flow.
- Ureteral jets are areas of color flow that represent urine entering the bladder from the ureters. A typical person will have several "jets" per minute on each side but it may take several minutes for a jet to occur, even without obstruction. ***The presence of bilateral ureteral jets effectively rules out a complete obstruction***.
- Ureteral jets are visualized at the posterior bladder, which is at the bottom of the screen in the transverse view (**see FIGURE 5.68B**).
- Presence of ureteral jets can be helpful in ruling out an obstructive process; however, absence of jets alone cannot rule in an obstructive process. More information and more imaging may be required.

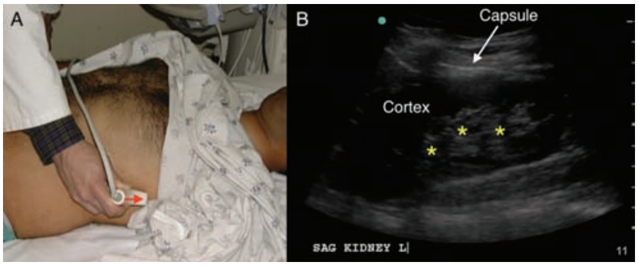


FIGURE 5.66 Longitudinal view of a normal left kidney. (A) Probe position. (B) Normal sonographic appearance. Note the brightly echogenic renal capsule (*arrow*), the hypoechoic outer cortex, and hyperechoic inner renal sinuses (*yellow asterisks*).

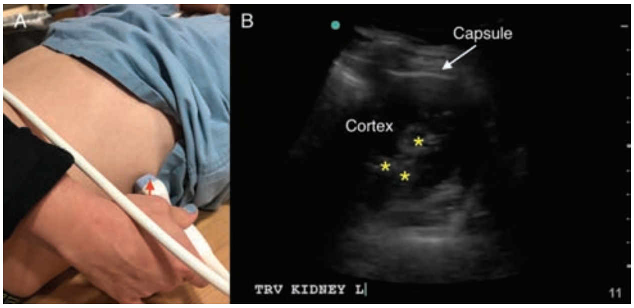


FIGURE 5.67 Transverse view of a normal left kidney. (A) Probe position. (B) Normal sonographic appearance. Note the brightly echogenic renal capsule (*arrow*), the hypoechoic outer cortex, and hyperechoic inner renal sinuses (*yellow asterisks*).

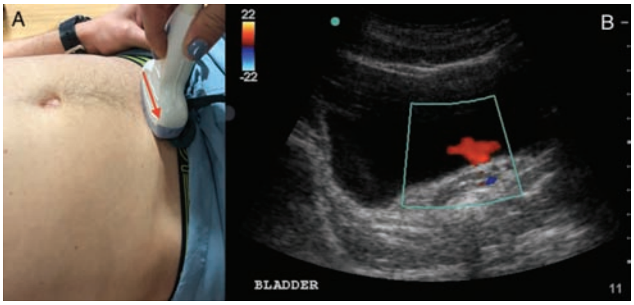


FIGURE 5.68 Transverse bladder view. (A) Probe position. (B) Sonographic appearance of a left ureteral jet.

SELECTED PATHOLOGY

Hydronephrosis

- Hydronephrosis is visualized on renal ultrasound when there is an obstructive process occurring distal to the kidney, and is visualized as dilated, anechoic renal calyces and renal pelvis (**FIGURE 5.69**).
- Note that it is a delayed finding as it takes time for the calyces and pelvis to dilate in response to the obstruction.
- Hydronephrosis is graded in severity according to the following criteria (**FIGURE 5.69**):
  - Mild hydronephrosis: Mild separation of calyces (spraying)
  - Moderate hydronephrosis: Dilation of major and minor calyces (bear claw)
  - Severe hydronephrosis: Entire sinuses are displaced by the dilated renal pelvis with thinning of the renal cortex

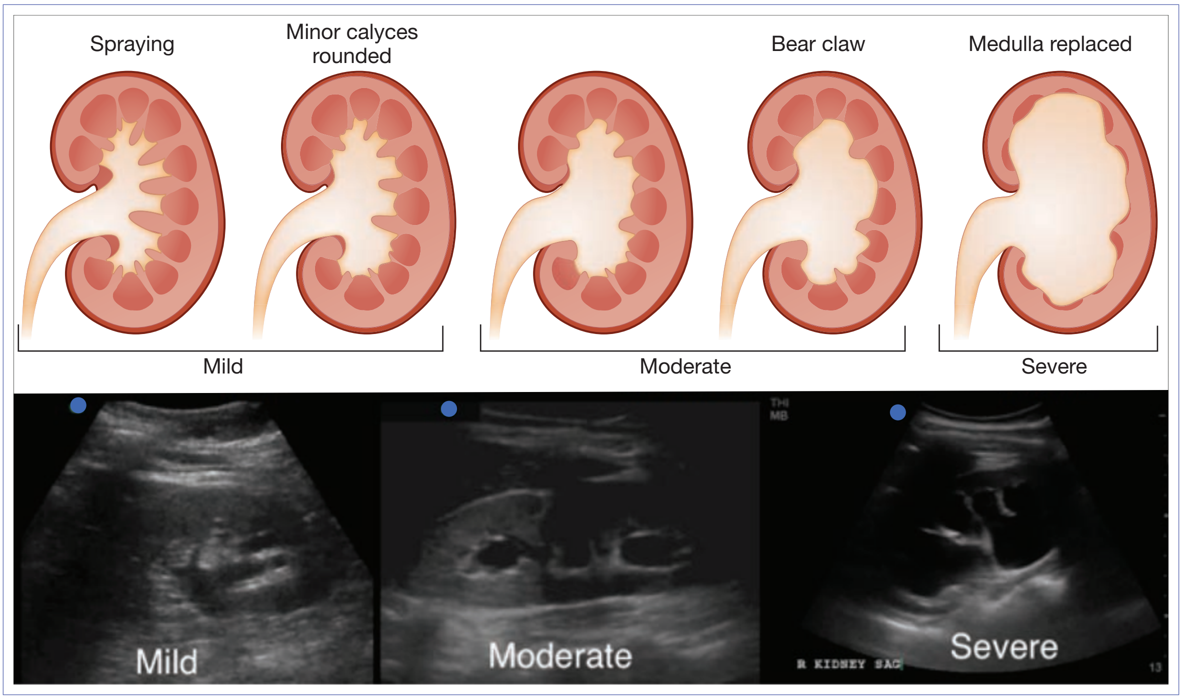


FIGURE 5.69 Degrees of hydronephrosis.

PEARLS

- Always scan both kidneys for comparison.
- Utilization of left and right lateral decubitus positioning can aid in visualization of the right and left kidney views, respectively.
- ***Always scan the bladder and consider urinary retention as a cause for bilateral hydronephrosis***.
- Consider the following causes of false-positive hydronephrosis: distensible collecting system in a well-hydrated patient, extrarenal pelvis, prominent renal vasculature, full bladder, postobstructive dilation, pregnancy-induced smooth muscle relaxation, vesicoureteral reflux, congenital megacalyces.
- Hydronephrosis may be confused with prominent renal vasculature. Use of color flow helps to differentiate these as hydronephrosis will not exhibit color flow.

FIRST-TRIMESTER PREGNANCY

Although bleeding and abdominal pain early in the first trimester are common, they should be considered signs of an ectopic pregnancy until proven otherwise. The most definitive way to prove that a patient does not have an ectopic pregnancy is to demonstrate an intrauterine pregnancy (IUP), as a heterotopic pregnancy is extremely rare in the general population. ***Note that in the setting of in-vitro fertilization and other assisted reproduction techniques, the likelihood of heterotopic pregnancies is increased, and the strategy outlined in this section may not apply as readily***.

A ***definitive*** IUP may be defined as an intrauterine gestational sac with a visible yolk sac or an intrauterine fetal pole with fetal heart tones. The only other ***definitive*** finding on first-trimester pelvic ultrasound is a ***definite*** ectopic—a pregnancy defined as a gestational sac with a yolk sac or a fetal pole with fetal heart tones that is outside of the uterus. An empty uterus or an intrauterine gestational sac without a yolk sac is considered an indeterminate study and requires additional workup.

Indications

- First-trimester pregnancy with pain or vaginal bleeding

Required Views

- Transabdominal views
  - Longitudinal and transverse views of the uterus
  - Gestational sac and yolk sac with dating
  - Fetal heart tones
- Transvaginal views
  - All of the preceding views plus bilateral adnexa

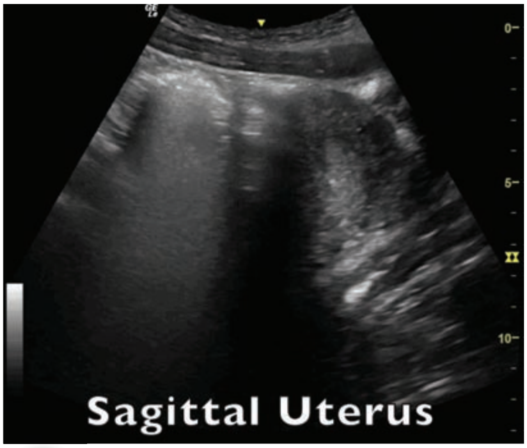
Preparation

- Probe choice
  - Transabdominal: Curvilinear/abdominal probe
  - Transvaginal: Endocavitary probe
- Patient positioning
  - Transabdominal: Supine position
  - Transvaginal: Lithotomy position

Procedure

TRANSABDOMINAL VIEWS

- Abdominal views are best obtained with a full bladder, which creates an acoustic window for optimal visualization of the uterus (**VIDEO 5.10**)
- Longitudinal and transverse views of the uterus
  - Position the abdominal probe in the longitudinal plane just above the pubic symphysis with the probe indicator toward the patient's head (**FIGURE 5.70A**).
  - Identify the anechoic bladder anterior to the uterine fundus (**see FIGURE 5.70B**).
  - Sweep the uterus from right to left; make sure to identify the vaginal stripe, cervix, and the endometrial stripe.
  - Rotate the probe 90 degrees counterclockwise to obtain a transverse view of the uterus. The probe indicator should be toward the patient's right (**FIGURE 5.71A**).



VIDEO 5.10 Normal first-trimester study.

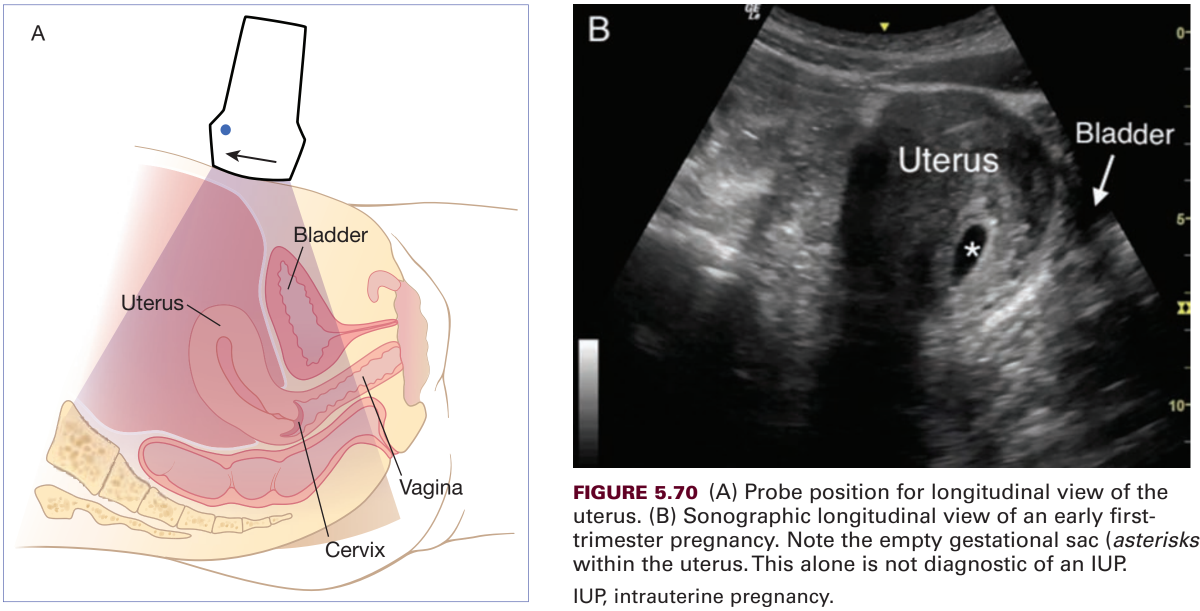


FIGURE 5.70 (A) Probe position for longitudinal view of the uterus. (B) Sonographic longitudinal view of an early first-trimester pregnancy. Note the empty gestational sac (*asterisks*) within the uterus. This alone is not diagnostic of an IUP.

IUP, intrauterine pregnancy.

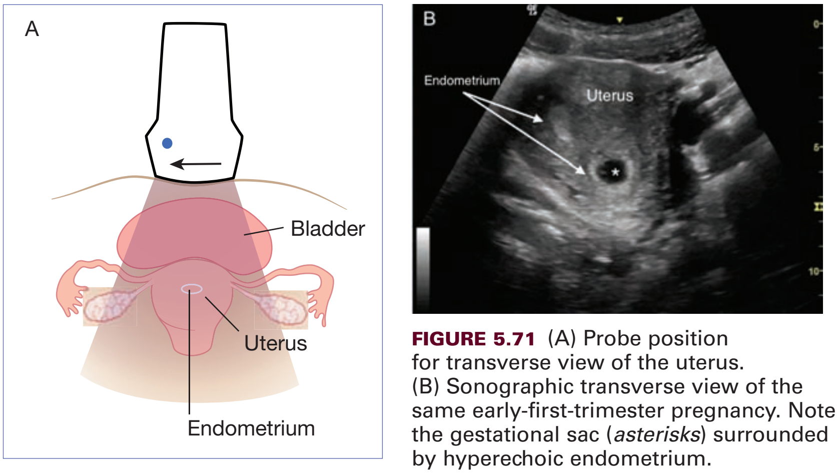


FIGURE 5.71 (A) Probe position for transverse view of the uterus. (B) Sonographic transverse view of the same early-first-trimester pregnancy. Note the gestational sac (*asterisks*) surrounded by hyperechoic endometrium.

  - Sweep the uterus from the top of the uterine fundus to the cervix.
  - If a gestational sac with a yolk sac is found in the transabdominal views (**FIGURE 5.71B**), proceed to the following additional images for dating and fetal heart tones. If an empty uterus or empty gestational sac is visualized, proceed to the transvaginal views.
- Gestational sac, yolk sac, and dating
  - The *gestational sac* is an anechoic, fluid-filled area that is eccentric to the endometrial stripe (**see FIGURE 5.70B**). ***Visualization of an empty gestational sac is not enough to prove an IUP***.
  - ***Visualization of a yolk sac within the gestational sac is 100% predictive of IUP***. The yolk sac is a 3- to 7-mm hyperechoic sphere first visualized within the gestational sac at between 5 and 6 weeks' gestational age. It is often referred to as a *balloon on a string* (**FIGURE 5.72**).
  - A *fetal pole* will appear about 2 days after the yolk sac and may be as small as 2 mm in length.
  - Measure the *crown–rump length* (CRL) to get the most accurate sonographic measure of gestational age. Measure the entirety of the fetal pole in the longest axis visualized. Do not include the yolk sac in your measurement (**FIGURE 5.73**).
  - Most modern ultrasound machines have an obstetrics preset that will calculate the gestational age automatically after selecting CRL measurement. Numerous free online calculators are available that can convert a millimeter CRL measurement into estimated gestational age.
- Fetal heart-tone measurement
  - Fetal heart motion appears around 5.5 weeks' estimated gestational age and should always be present if the fetal pole is greater than 7 mm.
  - ***Average fetal heart rates:***
    - *6 weeks = 110 bpm*
    - *7 weeks = 125 bpm*
    - *8 weeks = 160 bpm*
  - Record fetal heart motion in M-mode. M-mode shows depth and tissue motion over time. Align the M-mode

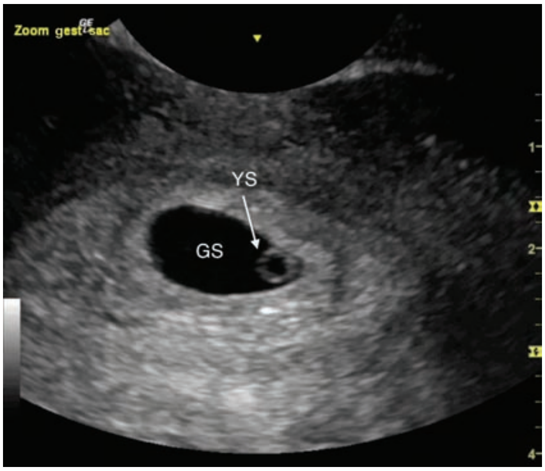


FIGURE 5.72 Early IUP. A YS is visualized on the lateral edge of the GS in this transvaginal view.

GS, gestational sac; IUP, intrauterine pregnancy; YS, yolk sac.

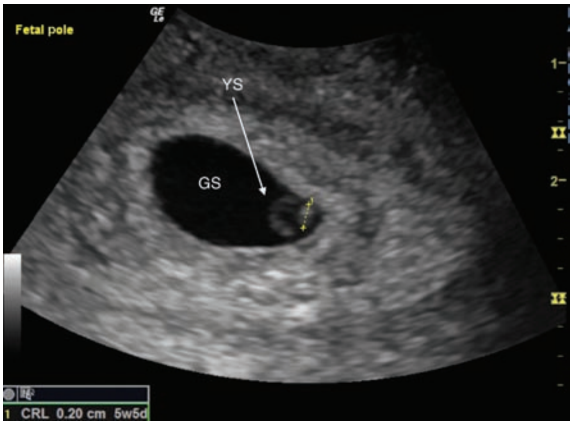


FIGURE 5.73 Fetal pole with CRL measuring 2 mm is consistent with a gestational age of 5 weeks and 5 days. Note that the CRL measurement does not include the YS.

CRL, crown–rump length; GS, gestational sac; YS, yolk sac.

cursor so that it strikes through the area where fetal heart motion is visualized. Find a repetitive pattern in the M-mode tracing that occurs at the same depth as the fetal heart. Measure peak-to-peak or trough-to-trough (**FIGURE 5.74**).
  - Again, most modern machines have an obstetrics preset that will calculate the fetal heart rate based on the measurement.

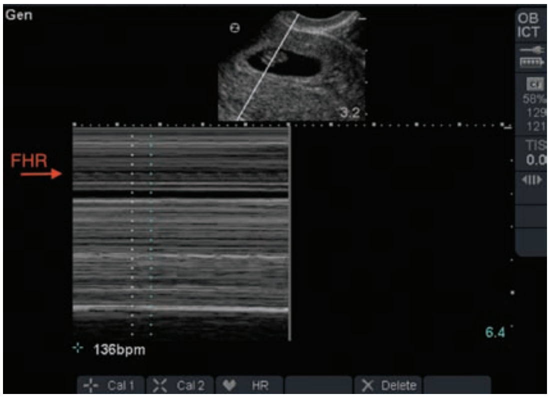


FIGURE 5.74 M-mode tracing of FHR at 136 bpm in a first-trimester pregnancy.

FHR, fetal heart rate.

TRANSVAGINAL VIEWS

- Always perform transabdominal sonography first to assess the position of the uterus; proceed to transvaginal sonography when unable to identify an IUP on the transabdominal views.
- Unlike transabdominal sonography, transvaginal sonography should be performed with an empty bladder.
- Relative contraindications to transvaginal sonography include recent gynecologic surgical procedures and an open cervical os.
- With every transvaginal exam, use a probe cover and follow high-level disinfectant procedures as mandated by your institution.
- Longitudinal and transverse views of the uterus
  - With the patient in the lithotomy position and undressed from the waist down, insert a covered transvaginal probe into the vagina with the probe indicator pointing toward the ceiling. This will provide a longitudinal view of the uterus (**FIGURE 5.75**).

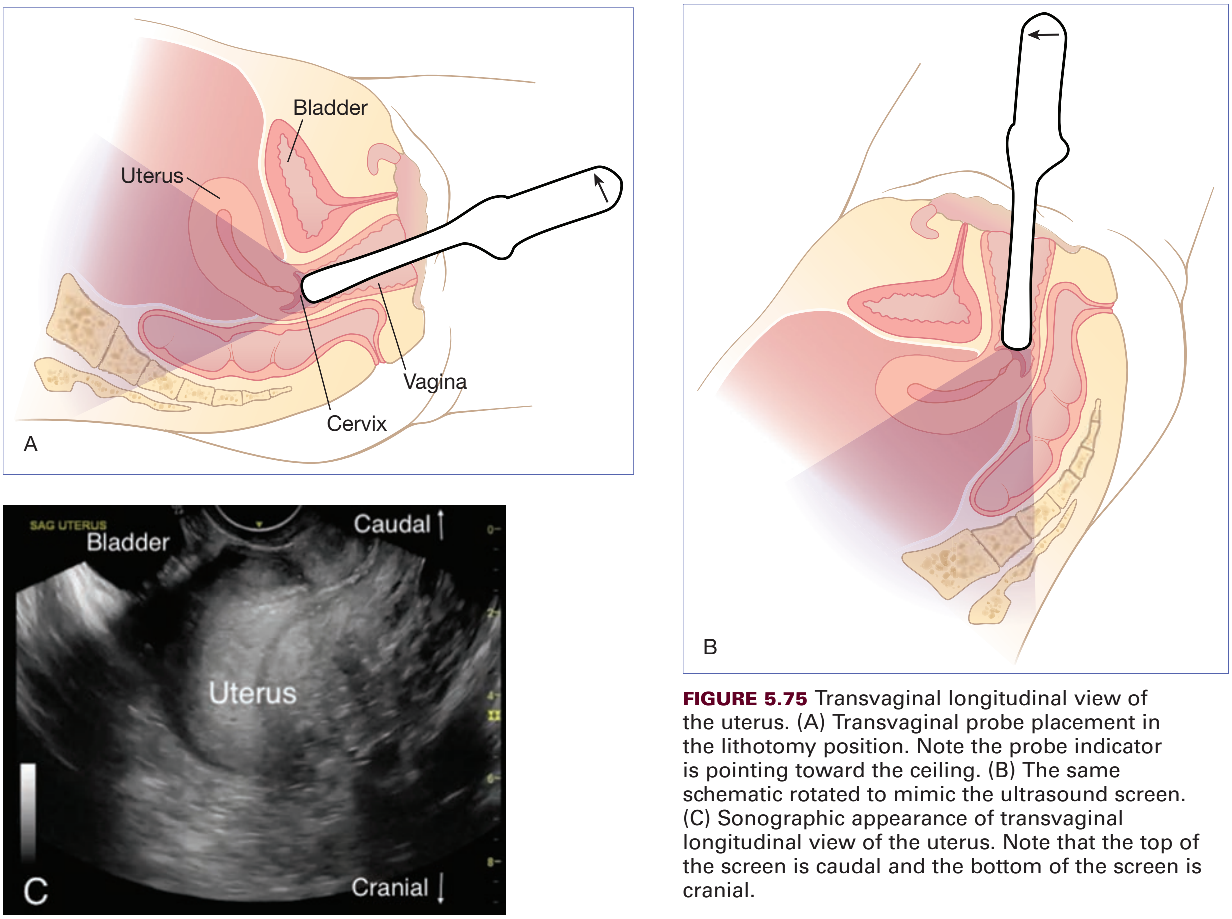


FIGURE 5.75 Transvaginal longitudinal view of the uterus. (A) Transvaginal probe placement in the lithotomy position. Note the probe indicator is pointing toward the ceiling. (B) The same schematic rotated to mimic the ultrasound screen. (C) Sonographic appearance of transvaginal longitudinal view of the uterus. Note that the top of the screen is caudal and the bottom of the screen is cranial.

  - Sweep the uterus from right to left, and make sure to identify the vaginal stripe, cervix, and the endometrial stripe. Try to identify an IUP as outlined previously.
  - With the probe still in the vaginal canal, rotate the probe 90 degrees counterclockwise to obtain a transverse view of the uterus. The probe indicator should be toward the patient's right (**FIGURE 5.76**).
  - Raise and lower your hand to sweep the uterus from the top of the uterine fundus to the cervix.
  - If an IUP is identified, proceed to dating and fetal heart rate measurements as outlined earlier.
- Adnexal sweeps
  - Adnexal sweeps are indicated when an IUP is not identified or when an IUP greater than 10 weeks' gestational age is identified to assess for ectopic and heterotopic pregnancies, respectively.
  - Keeping the probe in the transverse plane, move your hand to the patient's left with the ultrasound beam aiming to the patient's right so that the uterus is on the right of the screen and the right iliac vessels are on the left of the screen.
  - Sweep from the top of the uterine fundus to the cervix. The adnexal structures will lie between the uterus and the iliac vessels bilaterally. Look for the ovary and any adnexal masses that would be suggestive of an ectopic pregnancy.
  - Repeat the same steps with the left adnexa, this time moving your hand to the right so that the uterus is on the left of the screen and the iliac vessels are on the right (**FIGURE 5.77**).

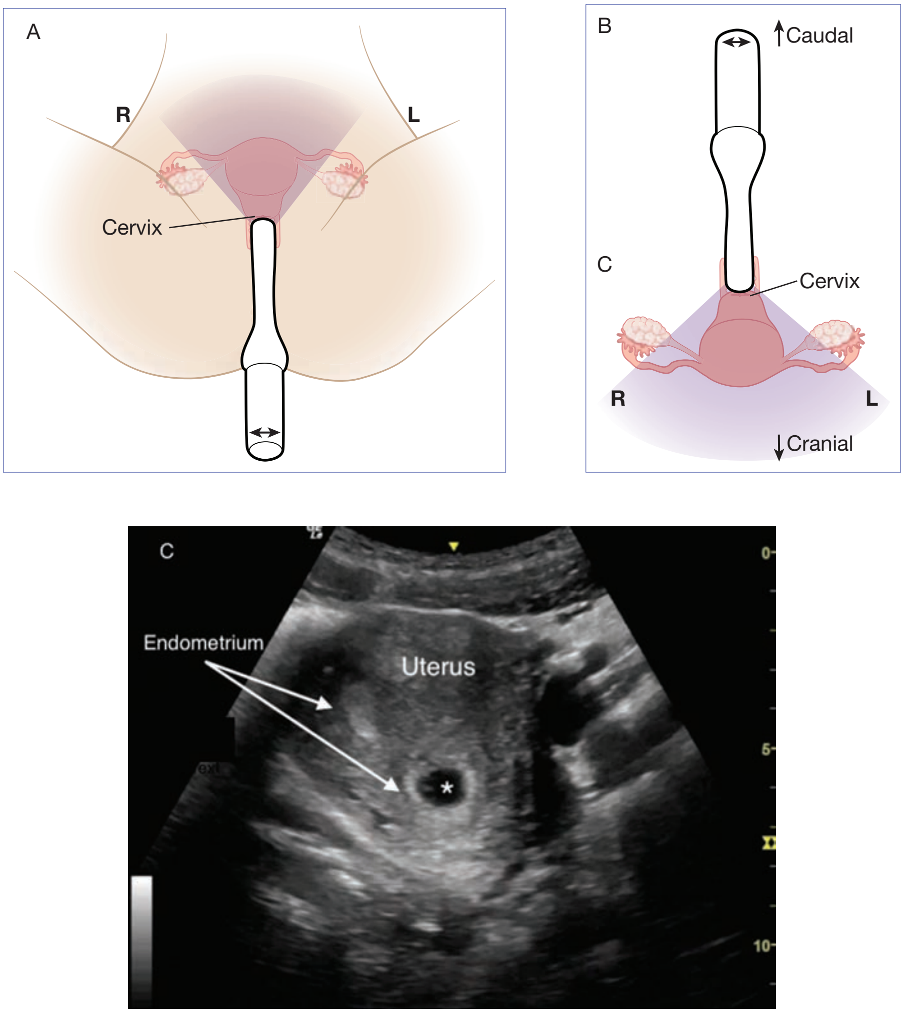


FIGURE 5.76 Transvaginal transverse view of the uterus. (A) Transvaginal probe placement in the lithotomy position. (B) The same schematic rotated to mimic the ultrasound screen. (C) Sonographic appearance of transvaginal transverse view of the uterus. Note that the top of the screen is caudal and the bottom of the screen is cranial.

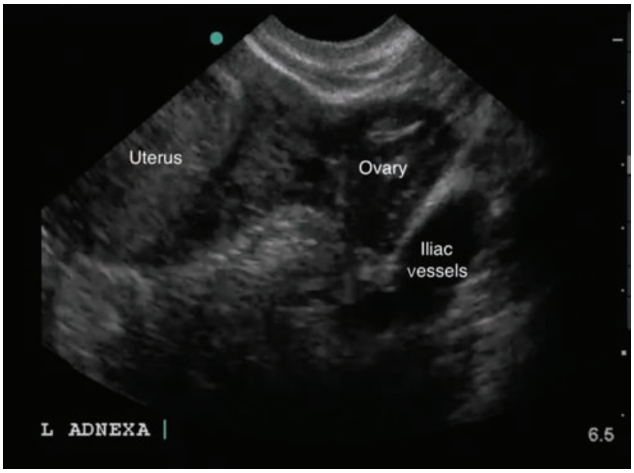

Uterus
Ovary
Iliac vessels
L ADNEXA
6.5

FIGURE 5.77 Transvaginal transverse view of a normal left ovary. Note the ovary is found between the uterus on the screen left and the iliac vessels on the screen right.

SELECTED PATHOLOGY

Ectopic Pregnancy

- ***An ectopic pregnancy can be diagnosed when a yolk sac or a fetal pole with fetal heart tones is visualized outside the uterus*** (**FIGURE 5.78**).
- Sonographic signs of concern for ectopic pregnancy include:
  - Thickened fallopian tube, sometimes referred to as a *bagel sign*.
  - Increased vascularity around the gestational sac on color flow, sometimes referred to as a "*ring-of-fire sign*."
  - Complex adnexal masses
  - Large amount of free fluid or heterogenous free fluid
- Get your gynecology consultants involved early whenever you suspect ectopic pregnancy.

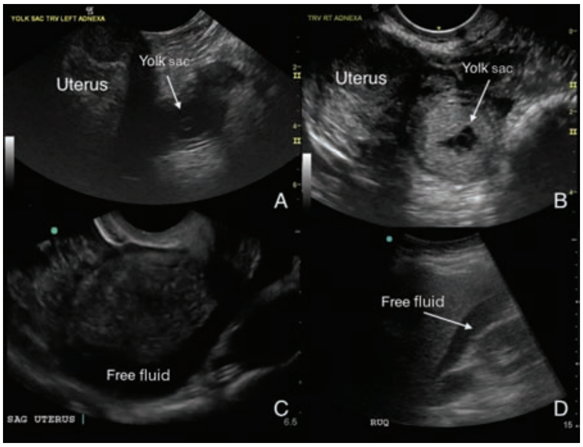

YOLK SAC TRV LEFT ADNEXA
Uterus
Yolk sac
A
TRV RT ADNEXA
Uterus
Yolk sac
B
Free fluid
SAG UTERUS
C
Free fluid
RUQ
D

FIGURE 5.78 Ectopic pregnancy. (A) A gestational sac with a yolk sac is visualized outside the uterus in the left adnexa. (B) A gestational sac with a yolk sac is visualized outside the uterus in the right adnexa. (C) A large amount of free pelvic fluid is seen surrounding the uterus. (D). Free fluid noted in Morison's pouch in a patient with a ruptured ectopic.

PEARLS

- Transabdominal pelvic ultrasound should be performed with a full bladder; transvaginal pelvic ultrasound should be performed with an empty bladder.
- Every first-trimester ultrasound will fall under one of three findings:
  1. IUP: Intrauterine gestational sac with a yolk sac or a fetal pole with fetal heart rate
  2. Definite ectopic: Yolk sac or fetal pole outside the uterus
  3. Indeterminate study: Empty uterus or intrauterine contents that do not meet IUP criteria
- Consider obtaining an RUQ/Morison's pouch view to assess for free peritoneal fluid, which in the right context may indicate a ruptured ectopic pregnancy.
- A POCUS demonstrating an IUP essentially rules out an ectopic pregnancy as a heterotopic pregnancy is exceptionally rare; be more cautious in patients undergoing assisted reproduction techniques.

CONCLUSIONS

Diagnostic ultrasound can be performed at the point of care in many patient care settings. With advances in technology, its use is likely to increase substantially in the near future. This chapter serves as a basic introduction to the many clinical situations in which POCUS can be extremely useful.

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UNIT III

Procedures for Airway Management

CHAPTER

6

Procedures for Basic Airway Management and Foreign-Body Removal

Benjamin Bloom, Jennifer Repanshek, and Keith Lafferty

BASIC AIRWAY MANAGEMENT

BACKGROUND

Although advanced airway management skills may be beyond the scope of many clinicians, it behooves any clinician who is treating patients with altered mental status or performing minor surgical procedures using sedatives and potentially large doses of local anesthetics, to have a fundamental understanding of basic airway maneuvers. Indeed, it is paramount for the clinician to recognize potential airway compromise and to act on it early, before its sequelae of obstruction, hypoxemia, and acidosis may ensue.

Knowledge of the airway anatomy is mandatory. An appreciation of the importance of proper airway tone in maintaining airflow is crucial. Any decrease in consciousness, whether it is via trauma, intoxication, pathology, or medications, may allow the tongue to fall against the posterior pharyngeal wall, as well as induce a decrease in tone of the pharyngeal soft tissue. This causes a collapse of the hypopharynx and may induce a partial and/or full airway occlusion.

PATIENT PRESENTATION

Signs of partial or complete airway obstruction include the following:

- Decrease in mentation
- Pooling of oral secretions
- Stridor or snoring
- Difficulty in phonation
- Hypoxemia may be a late sign
- Cyanosis may be a late sign

TREATMENT

Often, partial or complete airway obstruction can be overcome by simple manual airway maneuvers, such as the chin lift or jaw thrust, which overcome lax musculature and tongue occlusion of the posterior pharynx, especially in the patient with a decreased level of consciousness. Additional treatment modalities include supplemental oxygen, suctioning of secretions, and artificial airway devices.

Manual Airway Maneuvers

A chin lift or jaw thrust should be performed on every unconscious patient, as these patients are high risk for upper airway obstruction. ***This maneuver pulls the hyoid bone anteriorly, which in turn pulls the epiglottis and posterior tongue superiorly and anteriorly away from the posterior pharyngeal wall*** (**FIGURE 6.1**).

- The hyoid bone attaches the muscles of the floor of the mouth and the base of the tongue, the larynx below, and the epiglottis; elevating the hyoid (manual airway maneuvers) lifts all these structures away from the posterior pharyngeal wall and hence alleviates airway obstruction, which is prominent in the semi-/unconscious patient.
- In a cadaver study, Prasarn et al. (2014) have shown that the chin-lift maneuver increases movement at C1/C2 significantly more than the jaw-thrust maneuver (**FIGURE 6.2**).
- Note that a child's airway demands greater attentiveness as children have a relatively larger tongue and epiglottis and a smaller luminal airway diameter relative to adults.

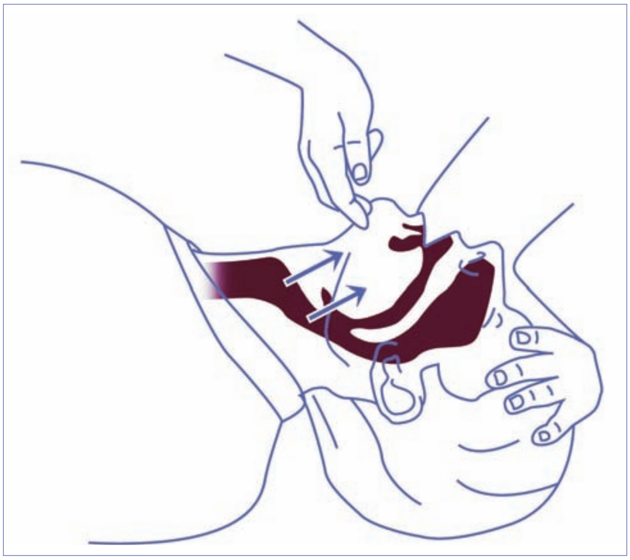


FIGURE 6.1 Illustration depicting sagittal view of chin lift with airway anatomy. This maneuver has been shown to increase movement at C1/C2 more than the jaw-thrust maneuver. For this reason, it is restricted to those patients without a possible cervical spine injury.

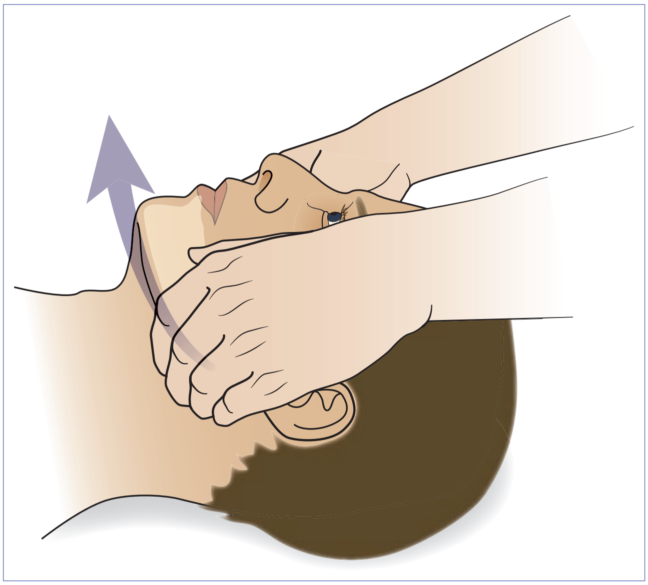


FIGURE 6.2 Illustration depicting sagittal view of jaw thrust. This maneuver has been shown to induce less cervical movement than the chin-lift maneuver. For this reason, it is recommended for those patients with a possible cervical spine injury.

Supplemental Oxygen

Besides proper head positioning, oxygenation is most efficient when the patient is upright, so ***elevate the head of the bed to at least 30 degrees when possible*** as this recruits otherwise atelectatic alveoli. Supplemental oxygenation (O_2) may be all that is required for patients with respiratory compromise. The signs of hypoxemia include agitation, cyanosis, and change in heart rate. ***A pulse oximeter and continuous measurement of end-tidal carbon dioxide ($ETCO_2$) should be used in all cases of procedural sedation. Furthermore, all patients with altered mentation should be assumed to have one of the following three reversible entities:***

- Hypoxia
- Hypoglycemia
- Opioid toxicity

Physiologically, it is key to keep a patient's oxygen saturation near 100% because when it gets down to 90%, the corresponding partial pressure of oxygen (PaO_2) is 60 mmHg, which is on the descending segment of the oxyhemoglobin dissociation curve. A further decrease will drop a patient's oxygenation rapidly and exponentially, potentially causing dysrhythmia, neuronal injury, and/or death. Supplemental oxygen delivery modalities are described in the text that follows.

An interplay of the following variables determines the fraction of inspired oxygen (FiO_2) in all delivery systems:

- Delivery apparatus size
- O_2 flow
- Tidal volume
- Respiratory rate

NASAL CANNULA

- Generally better tolerated than a mask
- Cannot deliver O_2 in excess of 6 L/min reliably under normal circumstances, as further increases in flow cause nasal irritation and are not well tolerated by the patient
- Not a closed system; there is significant air leak and mixing with room air, so the FiO_2 gain may be only modest
- Flows greater than 15 L/min may be utilized in rapid sequence intubation during apneic oxygenation (see Chapter 7; **FIGURE 6.3**)

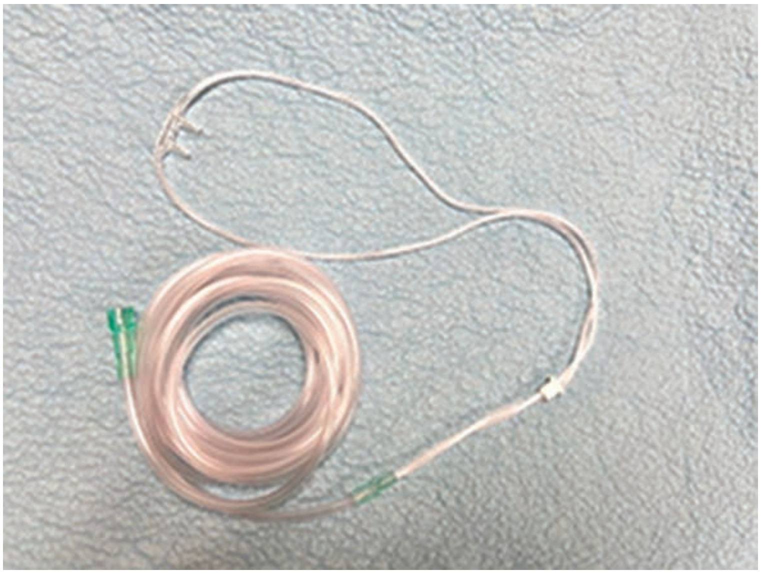


FIGURE 6.3 Photograph of nasal cannula.

SIMPLE O_2 MASK

- Is not as well tolerated as nasal cannula (NC).
- Delivers oxygen at 6 to 10 L/min.
- ***A minimum O_2 flow rate of 6 L/min must be maintained.***
- Note that room air is allowed to enter the mask through exhalation ports (**FIGURE 6.4**). The mask itself provides a slight reservoir of O_2 for inhalation. For these reasons, FiO_2 of 35% to 60% is all that is delivered.

NONREBREATHER MASK

- Contains one-way valves over the exhalation port, which allow egress of exhaled air while preventing the introduction of room air into the mask during inhalation.
- There is a one-way valve between the reservoir bag and the mask (**FIGURE 6.5**).
- Exhalation ports limit rebreathing of ***most*** expired gas room air.
- Leaks occur around the poorly sealed edges of the mask.
- The ambient air and exhaled gas remaining in the mask dilute the O_2 from the reservoir and prevent the mask from providing 100% oxygenation.
- Flow of 15 L/min in reality provides an FiO_2 of 70%.

“Flush rate” flows may be used during the preoxygenation phase of rapid sequence induction (RSI) by increasing the flow rate to 30 L/min therby creating an FiO_2 of 90% (see Chapter 7).

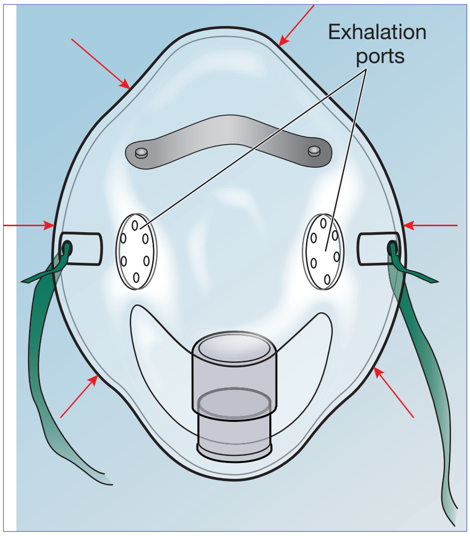


FIGURE 6.4 Illustration of a simple O_2 mask. Note exhalation ports allow the mixure of ambient room air with the O_2, diluting its concentration. Note small red arrows signify leaks when mask is on face.

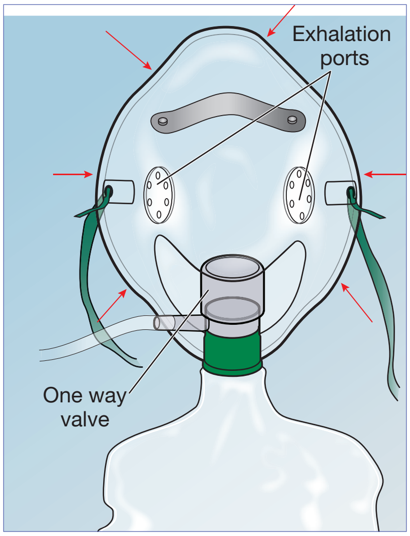
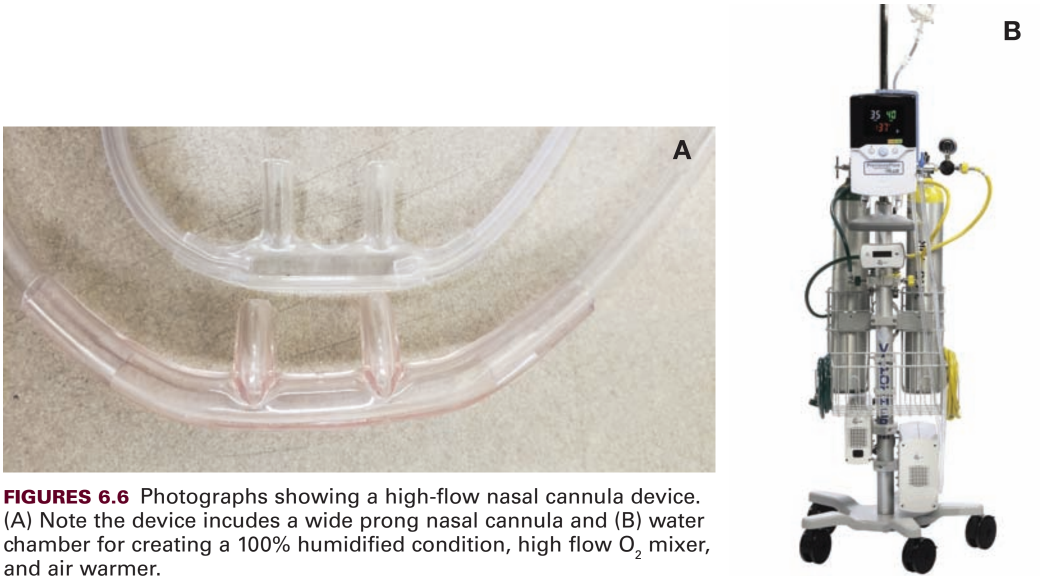


FIGURE 6.5 Illustration of a nonrebreather mask. Note oxygen reservoir (one-way valve) and the exhalation ports with a rudimentary one-way valve. Note small red arrows signify leaks when mask is on face.

HIGH-FLOW NASAL CANNULA

The concentration of oxygen increases as the flow rate of oxygen increases. Unlike atmospheric air, which is rich in water vapor, medical oxygen is not because it is stored as a dehydrated gas. As a result, flow rates are limited because membranes dry out quickly. When higher gas flows are utilized, it is imperative that the gas mixture is fully saturated with water vapor and heated close to body temperature, as the airway mucosa is otherwise unable to transfer sufficient heat and humidity at these supraphysiologic flow rates. High-flow nasal cannula (HFNC) simply provides the following to maximize the FiO_2 (**FIGURE 6.6**):

- Heat
- Humidity (100%)
- Wide-bore NC
- High flow rates, up to 60 L/min
- Generates an FiO_2 near 100%
- The high flow rates may also decrease physiological dead space by flushing expired carbon dioxide from the upper airway, a process that potentially explains the observed decrease in the work of breathing
- Allows the nasopharynx to act as an oxygen resevoir
- Provides up to 7.4 mm of Hg of positive end-expiratory pressure (PEEP)
- Better tolerated than face-mask oxygen and noninvasive positive-pressure ventilation (NPPV)
- In a *New England Journal of Medicine* (*NEJM*) article, Frat et al. (2015) have shown that HFNC oxygen therapy in patients with hypoxic repository failure (normo capnic) not only had a significant decrease in 90-day mortality, but also trended toward fewer intubations compared to face mask and NPPV therapy



FIGURES 6.6 Photographs showing a high-flow nasal cannula device. (A) Note the device incudes a wide prong nasal cannula and (B) water chamber for creating a 100% humidified condition, high flow O_2 mixer, and air warmer.

BAG-VALVE MASK

Using a bag-valve mask (BVM) is perhaps the most important skill in airway management because if you can oxygenate and ventilate the patient, you have time to consider all other airway modalities (**FIGURE 6.7**).

- Must be utilized when other methods fail
- Used in patients who are not able to breathe adequately on their own without the use of outside positive-pressure ventilation (PPV)
- Experience is critical as tight seal is a must: Numerous studies have shown that a two-handed technique provides a better seal than a one-handed technique; Gerstein et al. (2013) compared the traditional E-C clamp grip to the thenar eminence method and found that the later produced a tidal volume (TV) increase of an average of 110 mL
- Often used in conjunction with proper head positioning
- May require an oral or nasopharyngeal airway
- Problems encountered include inadequate TV and gastric distention
- An FiO_2 of nearly 100% can be achieved with a proper seal

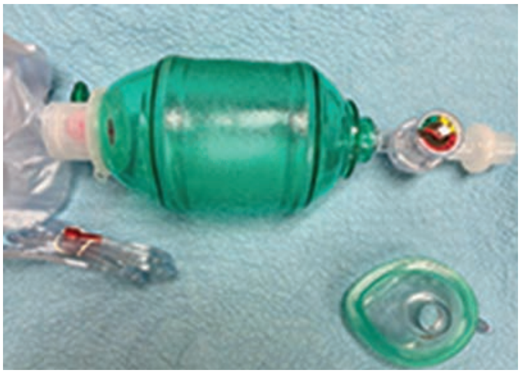


FIGURE 6.7 Photograph of a bag-valve mask.

Suctioning

On occasion, patient positioning and supplemental oxygen may be inadequate to achieve airway patency. To clear and maintain airway passage, blood, vomitus, and secretions may require suctioning.

A soft catheter-tip suction device may be used for gentle suction of the nasopharynx, especially for infants younger than 6 months of age, as they are obligate nasal breathers. This can also be used to clear tracheostomy cannulas. They are not designed for suctioning thick secretions and/or particulate matter as the lumen can easily become occluded by such material.

The Yankauer or tonsil-tip suction device is used to clear upper airway hemorrhage and secretions. A dental-tip suction device may also be used and may offer a greater ability to remove particulate matter because its tip is not rounded like the Yankauer, although it may cause more pharyngeal trauma. Oral and pharyngeal suctioning should be performed at intervals lasting no longer than 15 seconds to prevent further hypoxemia.

Complications of suctioning include the following:

- Induction of vomiting
- Possibility of transitioning to complete airway obstruction from partial obstruction if material cannot be suctioned
- Pharyngeal wall injury and bleeding
- Bradydysrhythmias

Artificial Airways

Artificial airways must be used when basic head positions do not alleviate tongue/pharyngeal obstruction. These devices will bypass obstructive tissue, allowing for smooth nonturbulent airflow. Airway adjuncts provide a conduit for ventilation, oxygenation, and suctioning, and can be used with BVM ventilation.

OROPHARYNGEAL AIRWAY

The oropharyngeal airway (OPA) is limited to use in the unconscious patient as it causes pharyngeal irritation that can induce vomiting in the awake patient with an intact gag reflex. It is composed of a piece of hard plastic with a central air channel and a flanged end that rests on the lips (**FIGURE 6.8**). This device essentially molds to the posterior tongue, separates the tongue from the posterior pharyngeal wall, and pushes the epiglottis forward.

NASOPHARYNGEAL AIRWAY

The nasopharyngeal airway (NPA) is made of a soft rubber material and is ***less noxious than the OPA*** in stimulating the gag reflex, and therefore can be used in an awake patient. The device is among the simplest of artificial airways and its use is highly effective in preventing the tongue from falling back against the posterior pharyngeal wall and obstructing the airway while acting as a conduit for oxygen. When appropriately sized and placed, it should rest just above the epiglottis (**FIGURE 6.9**).

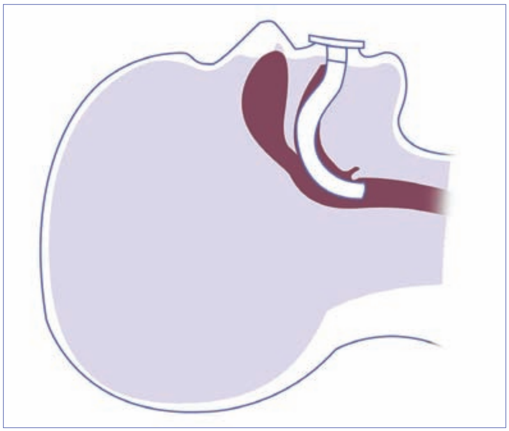


FIGURE 6.8 Illustration depicting oropharyngeal airway.

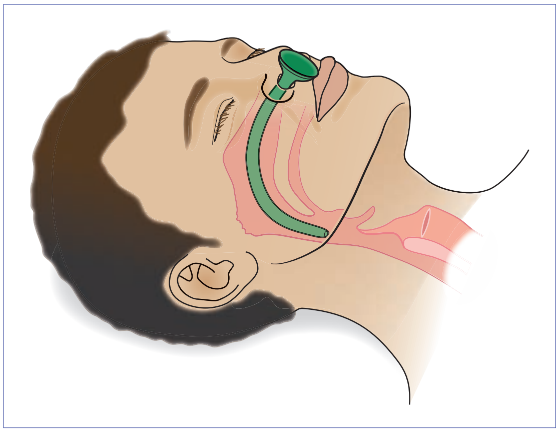


FIGURE 6.9 Illustration depicting nasopharyngeal airway management. Note the tip should lie just above the epiglottis.

PROCEDURE

Chin Lift

- Place the tips of the fingers beneath the patient's chin; apply pressure to mandible and not soft tissues.
- Lift the chin toward the ceiling; the head should tilt backward.
- Chin lift is relatively contraindicated in suspected spinal cord injury; however, airway management should take priority.

Jaw Thrust

- Place tips of the fingers behind angle of the mandible bilaterally.
- Lift mandible toward the ceiling.
- Do not extend the neck.
- Do not compress the soft tissue of the neck, as this can add to airway obstruction (**FIGURE 6.10**).

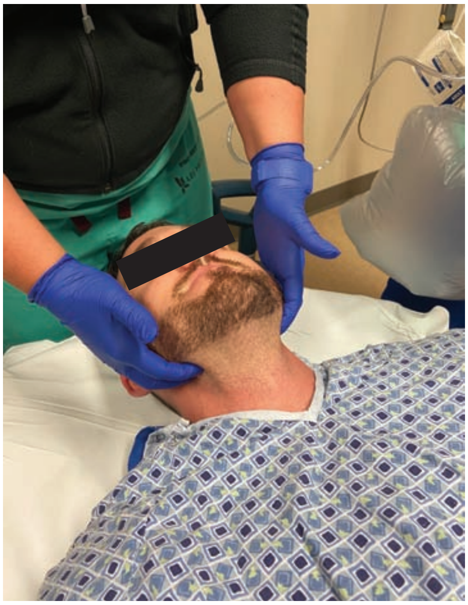


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FIGURE 6.10 Jaw-thrust maneuver. Note the fingers should be at the mandible angle lifting up toward the ceiling and not extending the neck. In this photo, the clinician has the fingers inadvertently in the soft tissue of the neck possibly increasing airway obstruction.

Bag-Valve Mask

- Place the face mask over the patient's mouth and nose; connect bag to oxygen source at minimum of 15 L/min.
- One-handed method—one hand forms a seal using the "C-E" grip, while the other hand squeezes the bag (**FIGURE 6.11**).
- Two-handed method—One rescuer achieves adequate seal, while the second rescuer squeezes the bag (**FIGURE 6.12**).

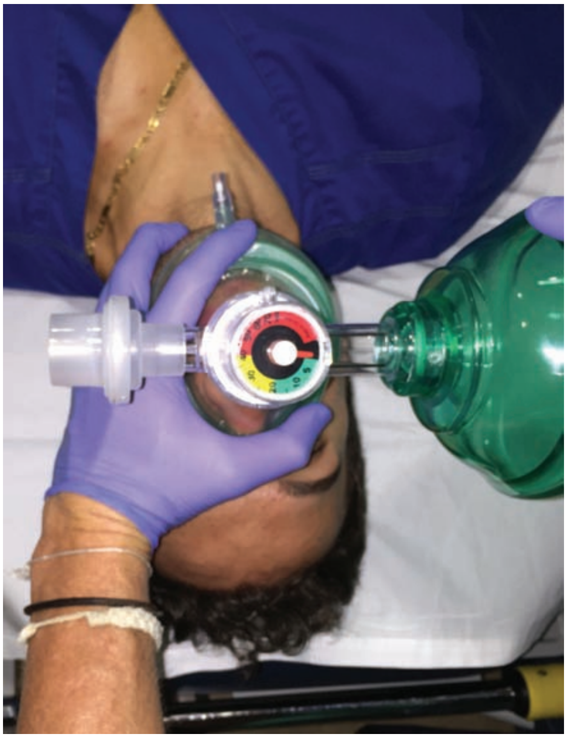

FIGURE 6.11 Bag-valve mask ventilation: one-person C-clamp technique.

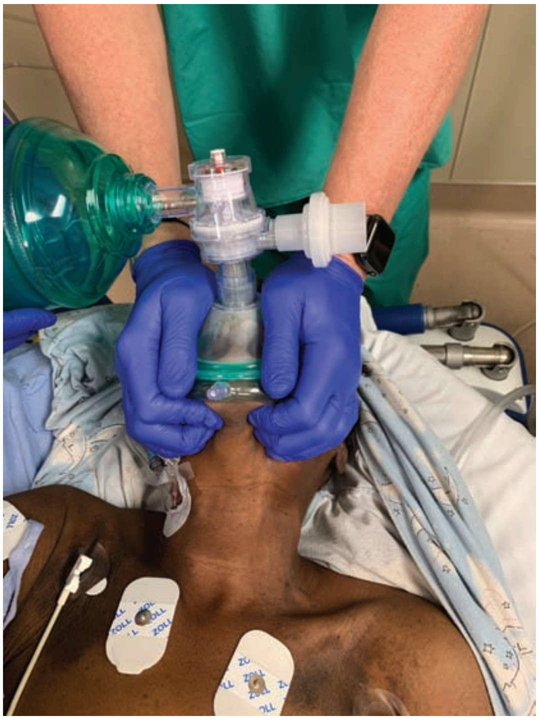

FIGURE 6.12 Bag-valve mask two-handed thenar eminence method is recommended. Note: The second person is squeezing the BVM and is not seen in this figure.

The thenar eminence method is recommended in order to achieve:

- Higher TVs
- Less energy expenditure by the clinician
- Better seal

To use the thenar eminence method:

- Compress the bag to deliver the smallest volume required to generate a visible chest rise.
- Firm posterior pressure applied to the cricoid to prevent gastric insufflation (the Sellick maneuver) was once the standard of care; however, recent literature disputes this clinical dogma.
- Dentures should be left in place to help ensure a better seal with the mask.
- Absolute contraindications include inability to ventilate due to lack of seal (i.e., deforming facial trauma) or inability to ventilate due to upper airway obstruction that cannot be overcome. A relative contraindication is bagging patients who are at high risk for aspiration.
- Complications of BVM use include failure to achieve adequate patency, inadequate oxygenation and ventilation from a poor mask seal, and aspiration secondary to gastric distention.
- Please refer to Chapter 7, Advanced Airway Management to read about this procedure in more detail.

Oropharyngeal Airway

- This method is contraindicated in the awake patient.
- Estimate proper size by placing device adjacent to the patient's face with the flange at the level of the anterior teeth and the distal component at the angle of the mandible.
- Patient should be in supine position.
- Tongue is depressed inferiorly with a tongue depressor.
- Technique 1: Place the concave side inferiorly until the distal part rests in the posterior hypopharynx.
- Technique 2: An alternative method
  would be to insert the device into the oral cavity in an inverted manner, then rotate it 180 degrees and advance until its distal end is pointed caudad in the hypopharynx.
- Complications include:
  - Vomiting
  - If device is too small, it can push the epiglottis inferiorly, occluding the glottic opening.
  - If the device is too big, it can impinge on and displace the tongue posteriorly and occlude the hypopharynx (**FIGURE 6.13**).

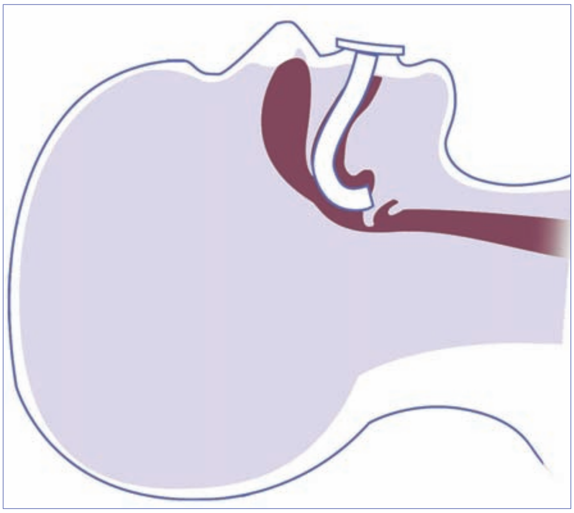

FIGURE 6.13 Illustration depicting incorrect size of oropharyngeal airway. Note that it is too distal and instead of lying above the epiglottis, it is pushing the epiglottis down, thereby obstructing the airway.

Nasopharyngeal Airway

- Use is contraindicated in facial trauma or basilar skull fracture.
- Estimate proper size by placing the flange end at the nares; the bevel tip should reach the lobule of the ear (**FIGURE 6.14**).
- Lubricate the device.
- Place in the nostril of least resistance.
- Insert posteriorly along the floor of the nares with the bevel toward the nasal septum.
- May have to rotate upon placement. If there is too much resistance, use other nostril.

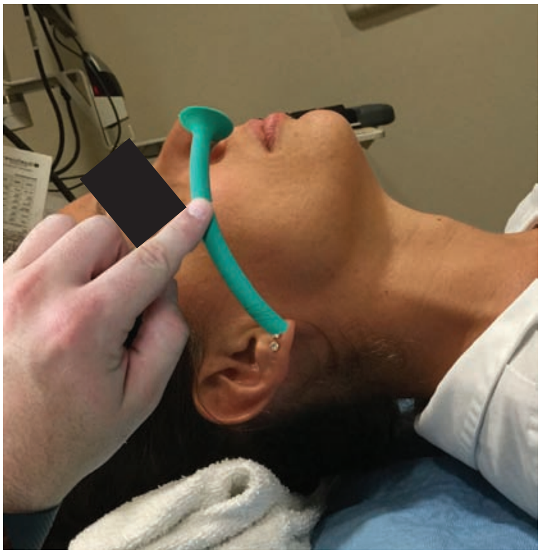
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FIGURE 6.14 Nasopharyngeal airway measurement.

COMPLICATIONS

Complications include:

- Epistaxis, injury to nasal mucosa, or adenoid tissue
- Sinusitis
- If device is too long, it can push epiglottis inferiorly, occluding the glottic opening (**FIGURE 6.15**)
- In the presence of a basilar skull fracture, device may be inadvertently placed through the cribriform plate into the anterior cranial fossa; do not use this device with midface trauma

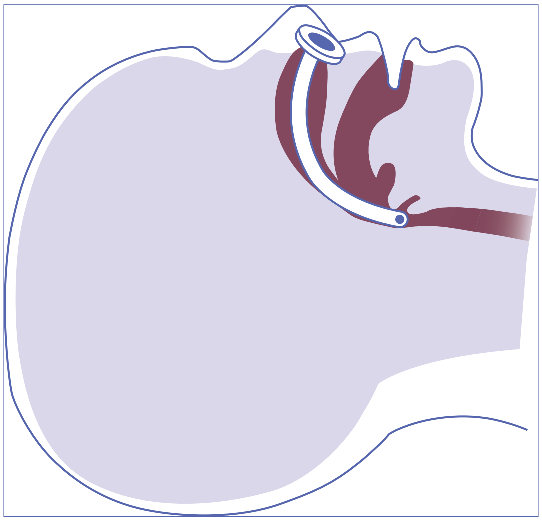

FIGURE 6.15 Illustration depicting incorrect size of a nasopharyngeal airway. The tip should lie just above the epiglottis; the nasopharyngeal airway shown is too long and is actually pushing on the epiglottis, causing further airway obstruction.

PEARLS

- Routinely check resuscitation equipment and have it nearby for procedures involving sedatives or large doses of local anesthetics.
- Be vigilant for signs of airway obstruction in patients who present with altered mental status or who have received sedatives.
- Basic airway maneuvers commonly alleviate partial airway obstruction.
- Because of increased cervical movement, the chin lift maneuver is restricted to those patients without a possible cervical spine injury.
- In almost all instances, the NPA is superior to the OPA.

FOREIGN-BODY REMOVAL

BACKGROUND

Airway foreign bodies can be divided into upper (from pharynx to main bronchi) and lower (distal to main bronchi) impactions. More than 3,000 deaths occur annually secondary to foreign-body aspirations; delayed presentation is common outside of acute asphyxiation. Lower airway tract foreign bodies are a diagnostic challenge because of the following: 80% occur in children younger than 3 years of age; the event is usually not witnessed and most foreign bodies (e.g., peanuts, hot dogs, and grapes) are radiolucent; because of this, one must maintain a high index of suspicion. In general, lower airway foreign bodies are not amenable to removal in the office or acute-care setting. Note that even though many signs are nonspecific at the initial presentation, 90% of children who have aspirated have a history of choking, coughing, wheezing, or stridor. No doubt, recurrent croup, pneumonia, atelectasis, pneumothorax, and pneumomediastinum should alert the clinician to arrange for a bronchoscopy, as this modality has decreased mortality from 50% to less than 1%. Even when the physical examination is unremarkable, if the history is possibly consistent with an acute aspiration (sudden symptoms or an object in the mouth that is suddenly missing), one must pursue this diagnosis.

More than two-thirds of aspirated foreign bodies are radiolucent; therefore, x-rays may show only indirect evidence of their presence, such as air trapping, mediastinal shift with expiration, atelectasis, pneumothorax, or pneumomediastinum. If the object is radiopaque, it may be seen oriented in the sagittal plane on the posteroanterior (PA) x-ray, as the cartilaginous tracheal rings are not fused posteriorly.

Sudden and acute asphyxiation induced by a lodged upper airway foreign body (oropharynx, hypopharynx, supraglottic, subglottic, or trachea) is a medical emergency. Any patient presenting with an acute upper airway aspiration who is not coughing or speaking or who is displaying respiratory distress, needs to be treated immediately. The cough reflex is the body's primary means of expelling a foreign body. This occurs via deep inspiration followed by a forced expiration against a closed glottis, which suddenly opens after high pressure forces it to do so. All immediate emergent treatments (Heimlich, back blow, and chest thrust maneuvers) essentially mimic this protective reflex. Patients presenting in this way should be treated as having a life-threatening emergency, and standard basic life support/ advanced life support (BLS/ALS) algorithms should be followed.

Further discussion pertains to patients who present with a fish/chicken bone or pill foreign-body sensation in the throat (**FIGURE 6.16**). As a rule, these patients are stable, give a clear history, and do not display any signs or symptoms of asphyxiation. They usually present immediately and can localize by pointing to the neck, where the foreign-body sensation is felt. Indeed, most of these patients have a minor mucosal defect, which appears as a foreign-body sensation. These usually heal within 24 hours.

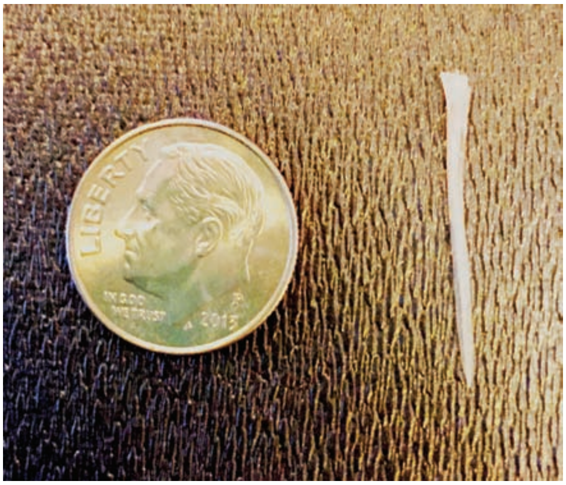

FIGURE 6.16 Photograph of a fish bone. Note the size in relation to a dime.

Although most foreign bodies are lodged in the hypopharynx, occasionally, with careful inspection with a tongue blade and light, some can be found in the oropharynx (tonsils and base of the tongue). Clinically, the challenge is determining whether this is a foreign body or, more common, an abrasion. Adding to this diagnostic challenge is the following:

- Plain x-rays are less than 50% sensitive, as not all fish or chicken bones are radiopaque secondary to their high cartilaginous content (**FIGURE 6.17**).
- Less than 25% of patients who complain of a foreign body actually have one found endoscopically.

The sensitivity of CT scans is more than 95% and they are widely available. Also, as a complementary modality, the nasopharyngeal laryngoscope (NPL) provides direct and complete visualization and is easy to use. Combining these two modalities essentially rules out the possibility of this diagnosis (**FIGURE 6.18**).

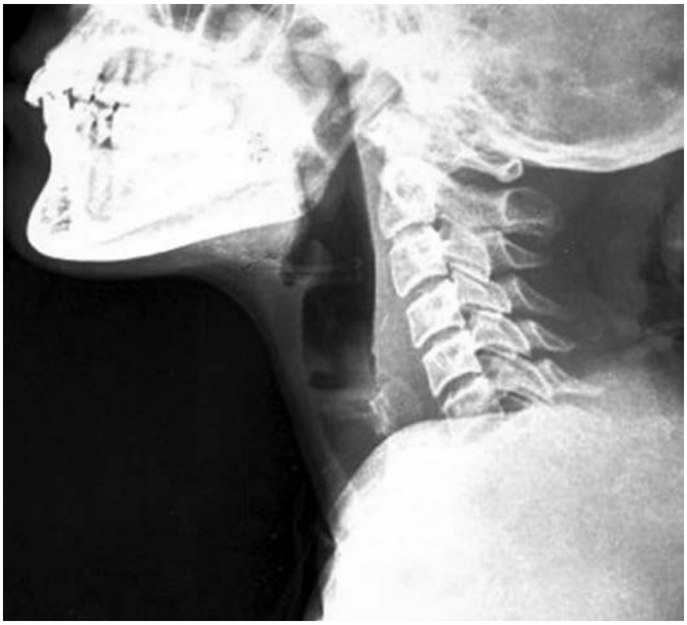

FIGURE 6.17 Lateral neck x-ray. Note that the fish bone is not seen.

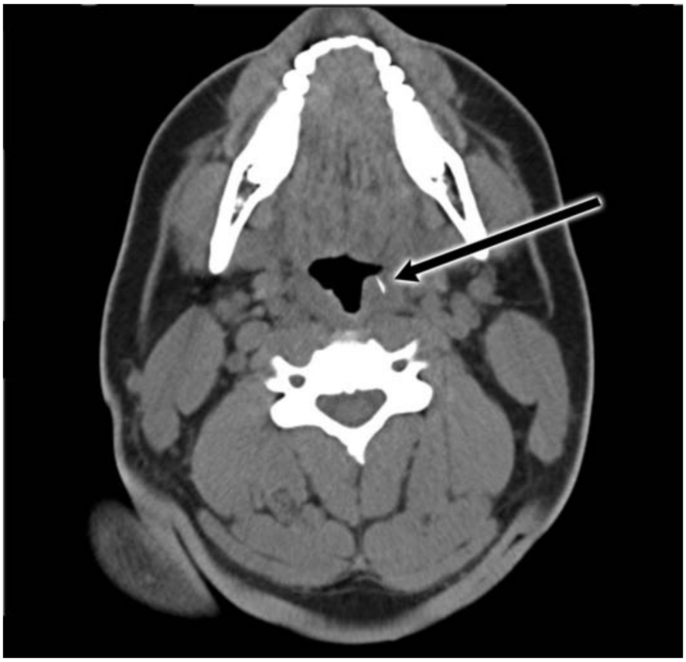

FIGURE 6.18 CT image of the neck. The fish bone is radiopaque.

Shaukat et al. (2017) report a case of a denture foreign body diagnosed via point-of-care ultrasound (POCUS) and revoved via video-assisted laryngoscopy (VAL). Ultrasound has been found to be more sensitive than x-ray, particularly in visualizing low-radiopaque foreign bodies.

Although CT has been found to be the most sensitive of the three imaging modalities in identifying foreign bodies of various materials, POCUS allows the flexibility of repeat and real-time use at the patient bedside, while also allowing use in the patient with a questionably unstable airway, whereas CT may be limited in this manner (**FIGURE 6.19**).

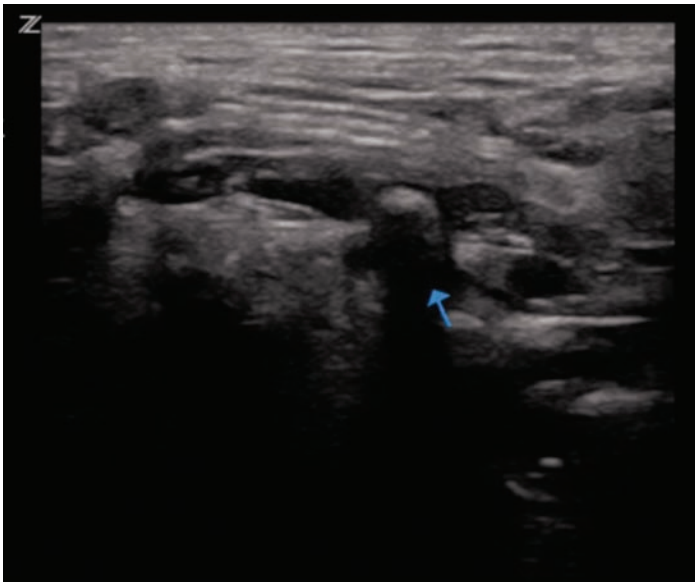

FIGURE 6.19 Transverse high-frequency POCUS image of the left hypopharyngeal area revealing hyperechoic material (denture) with posterior shadowing at the level of the cricoid cartilage.

POCUS, point-of-care ultrasound.

Source: Shaukat, N. M., Lenz, A., & Desai, P. (2017). Ultrasound-guided removal of hypopharyngeal foreign body in the emergency department. *Ultrasound*, 25(4), 245–247. https://doi.org/10.1177/1742271X17704681.

PATIENT PRESENTATION

- Patients usually present a few hours after the initial event.
- They sit upright and often point with a finger to the area of the throat where the foreign body is felt.
- They may experience odynophagia if the foreign body is placing pressure on the esophagus.

TREATMENT

The mainstay of treatment is identification and subsequent removal of the upper airway foreign body. Treatment differs depending on the clinical setting and one's familiarity with equipment, such as the direct laryngoscopy blade, and/or NPL. Patients should initially be evaluated with a careful oropharyngeal inspection. If the foreign body can be identified at this point and removed with forceps, the patient can be discharged. If further inspection is required, it usually includes the following modalities:

- Radiography:
  - CT scan
  - X-ray
  - POCUS
- Indirect laryngoscopy
- Direct laryngoscopy
- NPL

Of these modalities, only direct laryngoscopy allows for both identification and removal of the foreign body.

In recent years, fiberoptic visualization instruments, specifically the NPL, are being used with much more frequency (**FIGURE 6.20**). With a basic understanding of the upper airway anatomy, NPL use is easily mastered with practice. The device is attached to a light source and inserted through the naris, through the nasopharynx, and into the hypopharynx. Its distal end moves superiorly and inferiorly with the control of a dial using the dominant hand. Its lateral movement is controlled with the nondominant hand holding the end just outside the patient's naris (**FIGURE 6.21**).

In recent years, because of much-increased sensitivity, CT scans have replaced plain x-rays and the NPL has replaced indirect laryngoscopy.

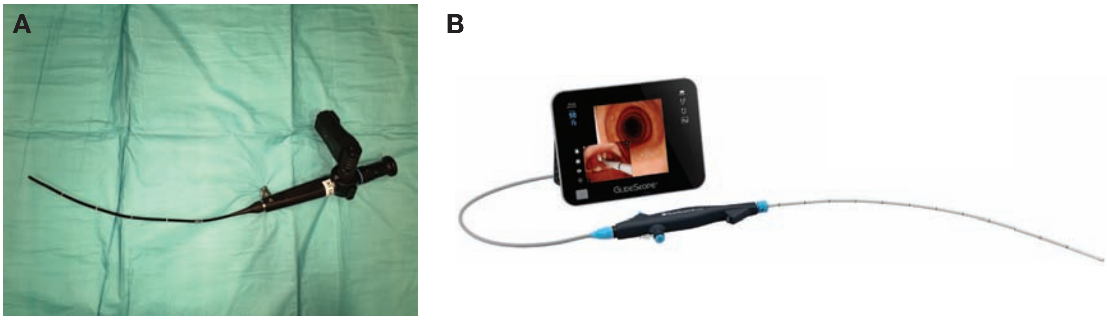

FIGURE 6.20 (A) Traditional nasopharyngeal laryngoscope. (B) Newer high-resolution nasopharyngeal/bronchoscope with larger, shared viewing area.

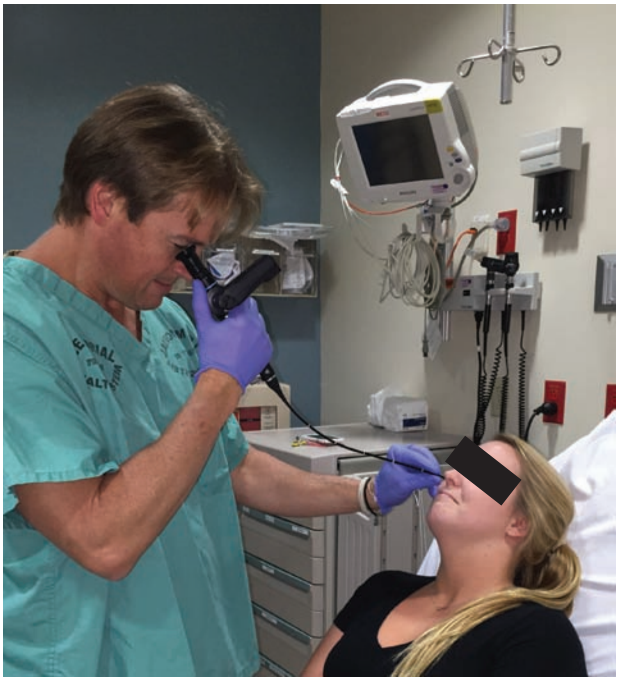

FIGURE 6.21 Nasopharyngeal laryngoscope technique.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Unfamiliarity with the use of

- NPL
- Laryngoscope

PROCEDURE PREPARATION

Nasopharyngeal Laryngoscopy

- NPL
- Light source
- Benzocaine spray, nebulized lidocaine (4%)
- Oxymetazoline or phenylephrine spray
- Water-based lubricant

Direct Laryngoscopy

- Laryngoscope and blade
- Benzocaine spray
- Viscous lidocaine, nebulized lidocaine
- Yankauer wall suction
- Magill forceps

Indirect Laryngoscopy

- Laryngeal (dental) mirror
- Head lamp
- Gauze
- Benzocaine spray

PROCEDURE

Indirect Laryngoscopy

- Patient should sit in an upright position leaning slightly forward (sniffing position) with the head leaning back on a fixed surface to prevent head movement.
- Spray the posterior pharynx with benzocaine.
- Place the dental mirror in warm water to prevent condensation.
- Wrap the tongue in gauze and grab it with the nondominant hand.
- Place the mirror upside down in the posterior oropharynx and visualize the hypopharyngeal/supraglottic structures.
- If a foreign body is visualized, proceed to direct laryngoscopy.

Nasopharyngeal Laryngoscopy

- Patient should sit in an upright position leaning slightly forward (sniffing position) with the head leaning back on a fixed surface to prevent head movement.
- Adequately anesthetize nares and posterior oropharynx with nebulized lidocaine, and/or benzocaine spray; vasoconstrict the nares with oxymetazoline or phenylephrine spray.
- Apply lubricant to the distal end of the NPL excluding the tip.
- Insert the NPL through the most patent naris (have the patient exhale through each naris separately while compressing the other).
- Insert the NPL posteriorly past the turbinates and visualize the posterior pharynx, hypopharynx, and supraglottic and glottic structures (**FIGURE 6.22**).
- If fogging occurs, move the distal end to rub against the mucosa.
- Have the patient say “e e e e,” as this moves the vocal cords together and moves the glottis away from the larynx, providing a better view.
- If a foreign body is visualized, proceed to direct laryngoscopy.

Direct Laryngoscopy

- After spraying the posterior pharynx with benzocaine, have the patient gargle for 1 minute three times with viscous lidocaine.
- Patient should be lying on a stretcher in the supine position.
- Clinician should be standing at the head of the bed.
- Check the light on the laryngoscope blade.
- Using the left hand, place the laryngoscope blade along the floor of the mouth and gently lift up at a 45-degree angle.
- Identify the foreign body and grasp with Magill forceps.
- VAL equipment may be used instead of direct laryngoscope (**FIGURE 6.23**).

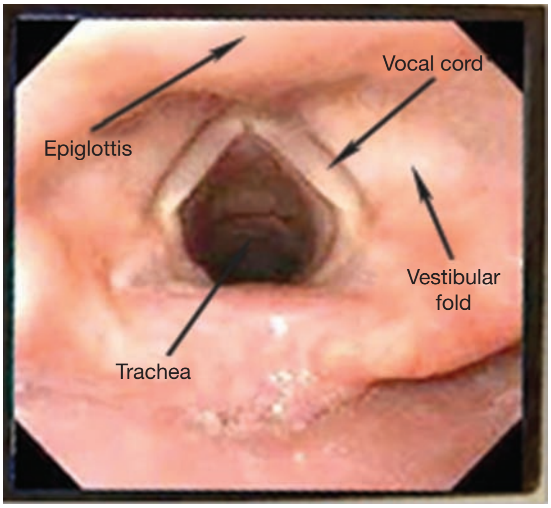

FIGURE 6.22 Nasopharyngeal laryngoscope visualization.

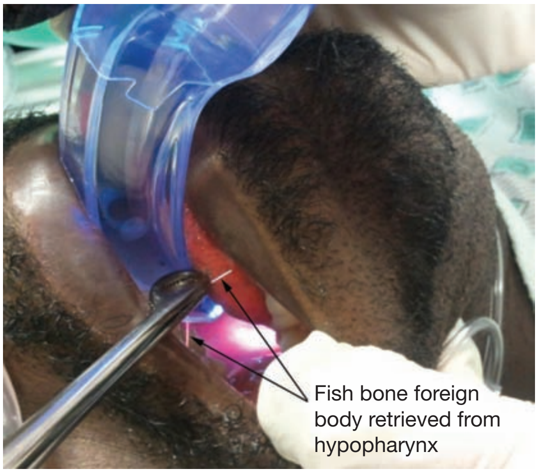

FIGURE 6.23 Retrieval of upper airway foreign body via video-assisted laryngoscopy. Note fish bone retrieval with forceps.

COMPLICATIONS

Retained Foreign Body

- Infection (retropharyngeal abscess)
- Asphyxiation

Nasopharyngeal Laryngoscopy

- Bleeding
- Abrasions
- Cough
- Vomiting

Direct Laryngoscopy

- Vomiting
- Bleeding
- Dental trauma

Indirect Laryngoscopy (Dental Mirror)

- Cough
- Vomiting

PEARLS

- Because of the low sensitivity of plain x-rays, x-rays can be eliminated in practices with access to an NPL and CT.
- CT scans have a sensitivity of more than 95% in identifying fish/chicken bones.
- POCUS may have a role in the diagnosis of airway foreign bodies; further investigation is warranted.
- If symptoms persist more than 24 hours, fiberoptic identification (via either NPL or VAL) and extraction are indicated, as these usually will not dislodge and secondary bacterial infection will ensue.

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CHAPTER 7

Advanced Airway Management

Benjamin Bloom, Jennifer Repanshek, and Keith Lafferty

BACKGROUND

Few procedures have the same capacity to affect a patient's outcome as advanced airway management. Specifically, an appreciation of airway anatomy and oxygenation physiology, coupled with the skills required for proper bag-valve mask (BVM) ventilation and endotracheal tube intubation (ETTI), are vital to one's competency and proficiency in caring for the critically ill patient with respiratory distress or respiratory failure. When basic airway skills—as described in Chapter 6—are inadequate in terms of oxygenation and ventilation, competency and dexterity in advanced airway techniques become critical to patient survival.

In general, patients may be divided into those who need an immediate airway ("crash airway") and those who can be managed in an orchestrated, stepwise, and escalating manner, potentially avoiding ETTI. The focus of this chapter is on rapid sequence intubation (RSI), expeditious pharmacologic sedation, and paralysis via video-assisted laryngoscopy (VAL) rather than direct laryngoscopy (DL). The reason behind this is analogous to central venous catheter (CVC) placement using ultrasound guidance rather than the landmark technique. Namely, as VAL equipment is becoming more prevalent in most modern acute-care arenas, an abundance of literature has been compiled supporting its ease of use (even for the novice intubator) and rate of first-pass success (FPS). Therefore, DL will not be covered in this chapter; however, any healthcare provider anticipating managing patients with the possibility of respiratory failure should learn this time-tested technique in the rare event that VAL equipment is not available.

ETTI is the preferred technique used to secure the airway and apply mechanical ventilation when advanced airway management is required. VAL offers the advantage of abandoning the need for alignment of the optical axes in the mouth, pharynx, and larynx in order to visualize the entrance of the glottis, and is therefore a more easily acquired skill. Standard ETTI via DL, performed by untrained medical personnel and those who perform it only occasionally, carries a high risk of failure. In several studies looking at the success rate of ETTI via DL performed by medical support staff, medical students, and novice anesthesia residents, the initial success rate varied between 35% and 65%. Mulcaster et al. (2003) and Konrad et al. (1998) have shown that in order to improve the success rate of DL to over 90%, one would require about 47 to 56 intubations. In stark contrast, VAL has been shown to be easily learned and highly successful with minimal training necessary. A Cochrane review concluded that VAL improves visualization of the glottis and may improve first-pass intubation success. Previous reports indicate that to maintain a 90% proficiency rate of ETTI, one should perform at least 20 procedures per year.

Silverberg et al. (2014) reported the first randomized controlled trial (RCT) comparing DL to VAL for urgent intubation by physicians in training. They randomized 117 patients requiring emergent ETTI to undergo either DL or VAL as the first method attempted. Successful intubations were achieved in all but two patients (who were then intubated). Intubation was successful at first pass 74% of the time using VAL, versus 40% using DL. There were no cases of intubation failure with VAL. In several patients, DL failed and VAL was used successfully (82% on the first pass after initial failure using DL).

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter

In a prospective trial, Howard-Quijano et al. (2008) compared 37 novice residents using VAL versus DL and found that the former yielded a 14% higher success rate and 14% fewer esophageal intubations. Nouruzi-Sedeh et al. (2009) evaluated medical personnel with no prior experience in ETTI (paramedic students, nurses, and medical students) and after a brief didactic/mannequin session compared their laryngoscopy skills in the operating room (OR) between VAL and DL. As in many other similar studies, they showed that VAL led to a significantly higher success rate (93%) as compared with DL (51%) *in nonphysicians with no prior laryngoscopy experience*. Subjects were also noted to have a dramatic improvement after only five ETTIs; they neared a 100% success rate using VAL. In a meta-analysis, Griesdale et al. (2012) looked at VAL compared with DL in 17 trials with 1,998 patients. The pooled relative risk for nondifficult intubations was 1.5 and for difficult intubations it was 3.5; the authors concluded that VAL improves glottic visualization, particularly in patients with potentially difficult airways. Finally, the National Emergency Airway Registry (NEAR), a multicenter international database of ED ETTI, cataloged over 12,000 intubations over a 2-year period. FPS for VAL versus DL was 90% and 81%, respectively. However, perhaps more important was that VAL outperformed DL in patients with difficult airways, with FPS of 83.5% and 71.2%, respectively. Historically, the literature has stated that when using DL and attempting to maintain a 90% proficiency rate of successful ETTI, performing at least 20 ETTI procedures has been recommended per year. Using VAL may greatly lessen the amount of procedures needed per year to maintain mastery and confidence.

In addition to anatomy, oxygenation physiology, VAL, RSI, and ETTI, this chapter also touches on the following:

- Noninvasive positive-pressure ventilation (NIPPV)
  - Bi-level positive airway pressure (BIPAP)
  - BVM ventilation
    - Covered in Chapter 6 as well
  - Supraglottic airways (SGAs)

Anatomy

UPPER AIRWAY

Pertinent upper airway anatomical structures/divisions can be divided into the following regions (**FIGURE 7.1**):

- *Nasal cavity*
  - Conduit via nares for air entry into the pulmonary system
- *Oral cavity*
  - Consists of the upper and lower teeth, the tongue and floor of the mouth, and the hard palate

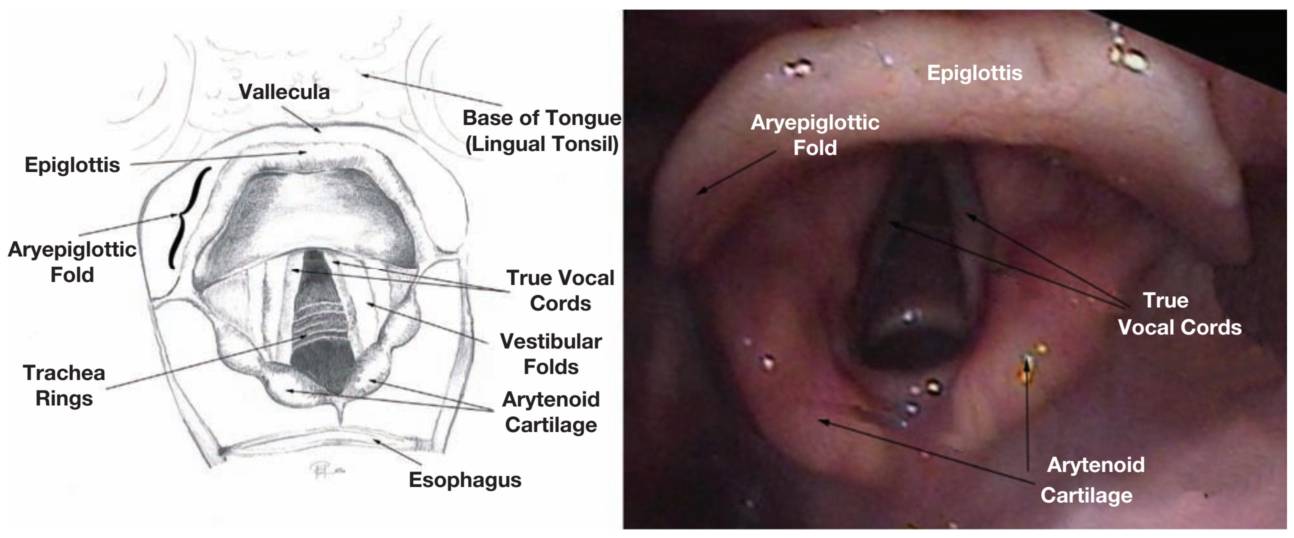

FIGURE 7.1 Airway anatomy.

- *Oropharynx*
  - Extends from the soft palate and uvula, to the level of the hyoid bone
  - When its tone is diminished (e.g., due to sedatives and/or cerebral insult), the tongue is the principal source of obstruction as it falls posteriorly against the pharyngeal wall in a supine patient.
  - It arises/attaches from/to the hyoid bone and all basic airway maneuvers (chin lift, jaw thrust) elevate the hyoid bone and therefore bring the tongue anteriorly, lifting it off of the pharyngeal wall.
- *Nasopharynx/nasal airway*
  - Extends from the back of the internal nasal cavity to the soft palate.
- *Laryngopharynx*
  - Begins at the level of the hyoid bone and extends downward; here it branches into two passages: the anterior larynx and the posterior esophagus.
- *Larynx*
  - The major cartilaginous skeleton of the larynx is formed by the thyroid cartilage anteriorly, the inferior cricoid cartilage circumferentially, and the cartilagin.
  - The larynx also contains the epiglottis superiorly, which varies in size and acts as a cape draping the antero-lateral surfaces of the vocal cords.
  - The triangular orifice between the vocal cords is called the *glottic opening* and is the entry point to the larynx.
  - In the adult, the glottis is the narrowest point, whereas in small children the subglottic area is narrowest.
  - Patency of the glottic opening is dependent on muscle tone.
  - During difficult laryngoscopy, the posterior arytenoids may be the only structure visualized and one can guide the endotracheal tube (ETT) into the glottic opening by guiding its tip anteriorly, knowing that these structures form the base of the triangle formed by the attaching vocal cords.
  - A bougie device may be used in this instance to act as a "guidewire" for the ETT.
- *Trachea*
  - It measures 12 cm in length from the glottic opening to carina.
  - The carina normally lies at the T4 to T5 interspace, so the ETT tip needs to be at least 5 cm above this to allow for the ±2-cm movement that occurs with head and neck movement (**FIGURE 7.2**).
  - Ten percent of ETTs migrate and can lead to serious complications, such as mainstem intubation or supraglottic displacement.

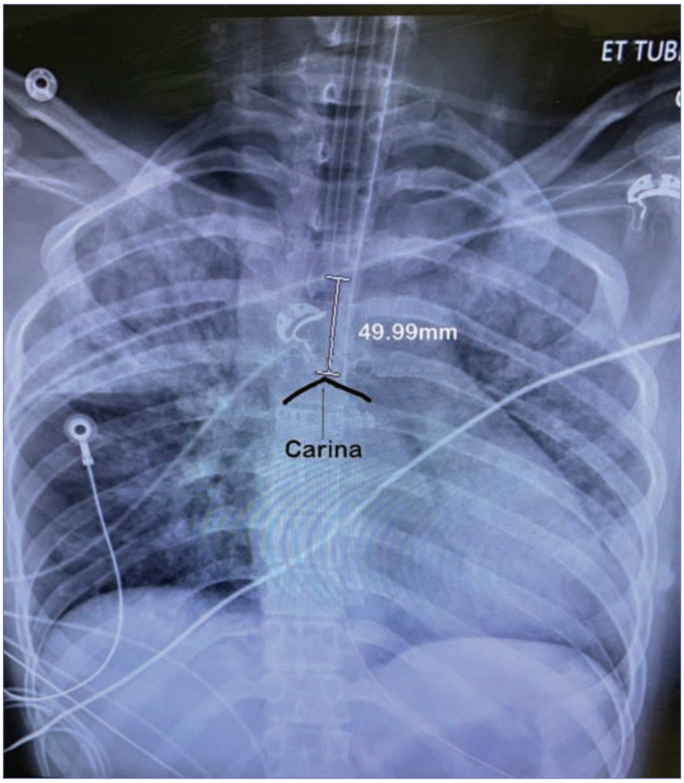

FIGURE 7.2 Properly placed ETT with regard to height above the carina. Note that a CXR does not rule out an esophageal intubation.

CXR, chest x-ray; ETT, endotracheal tube.

PEDIATRIC AIRWAY ANATOMY

There are some fundamental anatomical differences between the pediatric and adult airways. These lead to easier airway obstruction in children, a glottic opening that is more difficult to visualize, and the potential for additional complications.

- *Relatively large occiput*
  - This leads to inherent neck flexion when supine and therefore causes airway obstruction.
  - Infants and small children may require a shoulder roll to assist with neck extension.
- *Oropharynx*
  - Mouth is smaller proportionally, whereas the tongue is larger proportionally.
- *Glottis* is more cephalad and anterior.
  - The glottic opening as one ages:
  - Infancy—C1
    - This acute take off from the oropharynx causes the glottic opening to be difficult to visualize.
  - Age 7—C3/C4
  - Adulthood—C5/C6
- *Epiglottis*
  - Floppy is due to a more lax hypoepiglottic ligament.
  - This obstructs visualization of the anterior glottic opening.
  - Traditional teaching is to therefore use a straight Miller blade during DL to displace the epiglottis directly rather than the curved Macintosh blade, which displaces the epiglottis indirectly via the valleculae.
- *Laryngeal cartilage*
  - More compliant than in the adult and partial airway obstruction via dynamic collapse secondary to negative intraluminal pressure and is more likely to occur in the pediatric airway.
- *Trachea*
  - The pediatric trachea is both shorter and narrower than that of the adult.
  - Its shorter length (4–5 cm in newborns, 12 cm in adults) increases the risk of endobronchial intubation; *subsequently, there is less margin for error in ETT depth in children.*
  - The pediatric trachea is narrowest at the level of the cricoid cartilage.
  - The adult trachea is narrowest at the level of the vocal cords.
  - This subglottic narrowing is subject to edema and stenosis if the wrong-sized ETT is used.
- Poiseuille's law states that resistance to a gas flowing through a tube is inversely proportional to the fourth power of the radius of the tube.

$$\text{Flow Rate} = \text{radius}^4/\text{length}$$

  Therefore, a small change in the pediatric airway size (due to edema or inflammation) causes a greater increase in air resistance than a similar change in the corresponding adult airway (**TABLE 7.1**).

- *Oxygen consumption*
  - O_2 consumption is faster in the pediatric patient, resulting in shorter safe apnea times, placing pediatric patients at greater risk of iatrogenic hypoxia.

POSITIONING

Keeping knowledge of anatomy in mind, optimal patient positioning is vital for successful advanced airway management and ETTI. If the awake patient is spontaneously breathing but in respiratory distress, not yet requiring BVM, SGA placement, or ETTI, the patient should remain in the upright position, especially during the preoxygenation phase. In the obtunded

TABLE 7.1 Poiseuille's Law: Demonstrating the Effect of Decreasing Airway Diameter in Pediatric Versus Adult Patients

Airway	Adult	Pediatric
Decreasing by 1 cm	8 → 7 cm	4 → 3 cm
Resistance	↑ 3x	↑ 16x
Cross-sectional area	↓ 44%	↓ 75%

or chemically sedated patient undergoing BVM, SGA placement, or ETTI, the goal of positioning is to create the least obstructive anatomical alignment of the upper airway for ease of the patient's breathing. The fundamental principles are:

- Separate the tongue from the posterior pharyngeal wall.
- Align the three upper airway axes to the most similar angles possible (**FIGURE 7.3**). The three axes are the following:
  - Oral axis (OA)
  - Pharyngeal axis (PA)
  - Laryngeal axis (LA)

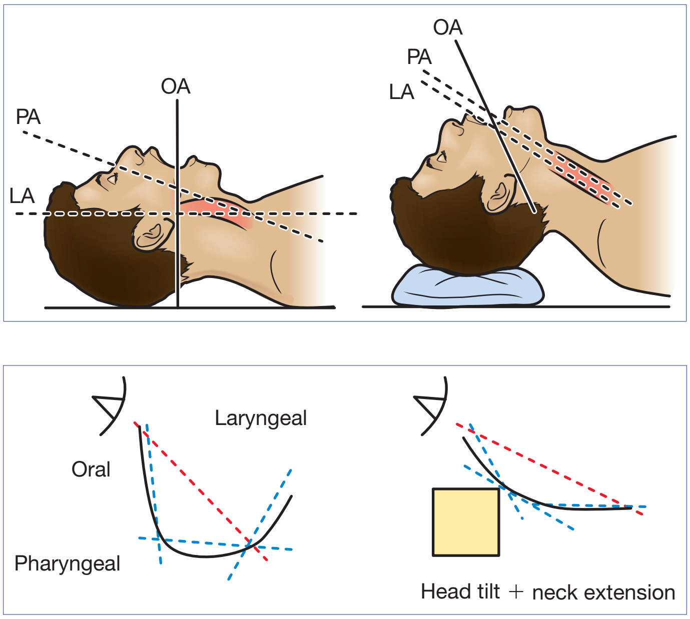

FIGURE 7.3 Oral axis, pharyngeal axis, and the laryngeal axis. Note that compared to the oropharyngeal curve, the pharyngolaryngeal curve is much more angled.

LA, laryngeal axis; OA, oral axis; PA, pharyngeal axis.

As stated earlier, the most common cause of upper airway obstruction is posterior displacement of the tongue against the pharyngeal wall, usually secondary to loss of tone and partial collapse of the pharyngeal soft tissue. A classic example of this is seen in patients with obstructive sleep apnea. As described in Chapter 6, basic airway maneuvers are simple interventions that can be performed by any healthcare provider, even with minimal training, in order to alleviate this obstruction:

Chin lift/jaw thrust: These manipulations elevate the mandible and hyoid bone and therefore move the tongue anteriorly, lifting it away from the pharyngeal wall, alleviating obstruction.

In the neutral supine position, the OA forms roughly a 90-degree axis in relation to the LA and inherently creates a technical challenge in terms of glottic visualization. In order to align the upper airway axes, and subsequently decrease airway resistance, the classic teaching is to place the supine patient in the "sniffing" position with slight neck flexion and a head elevation of 6 to 7 cm, such that the external auditory canal is parallel with the sternum (**FIGURE 7.4**).

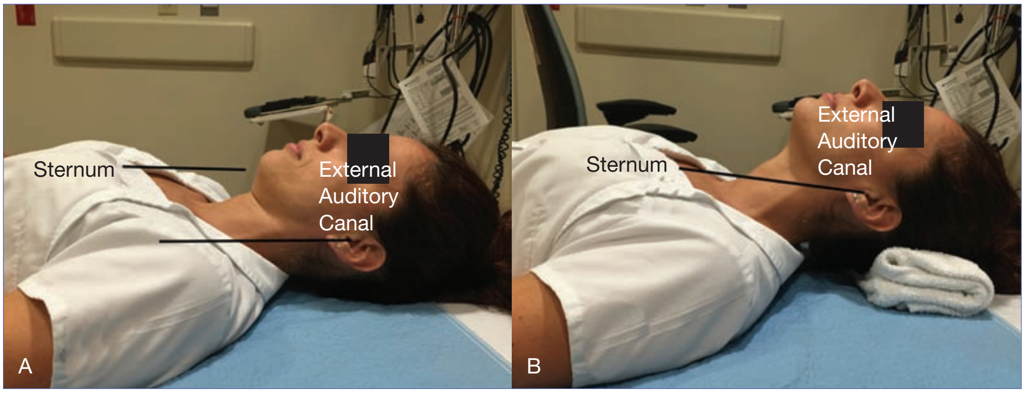

FIGURE 7.4 External auditory canal aligned with sternum. Note that in (A) the external auditory canal is not aligned with the sternal line and positioning is therefore incorrect. (B) shows correct alignment.

However, recently this classic teaching has been scrutinized and other positioning techniques have been reported in anesthesia, critical care, and emergency medicine literature. For example, a 2012 Cochrane review of 2,759 adult patients undergoing ETTI failed to show improvement of glottic visualization, rates of FPS, or decreased time to intubation for patients in the sniffing position. The sniffing position was, however, associated with easier intubation conditions, as determined by a standardized reporting scale, compared to simple head extension. However, the literature is somewhat contradictive in regard to the benefit of the head/torso-up position (**FIGURE 7.5**)

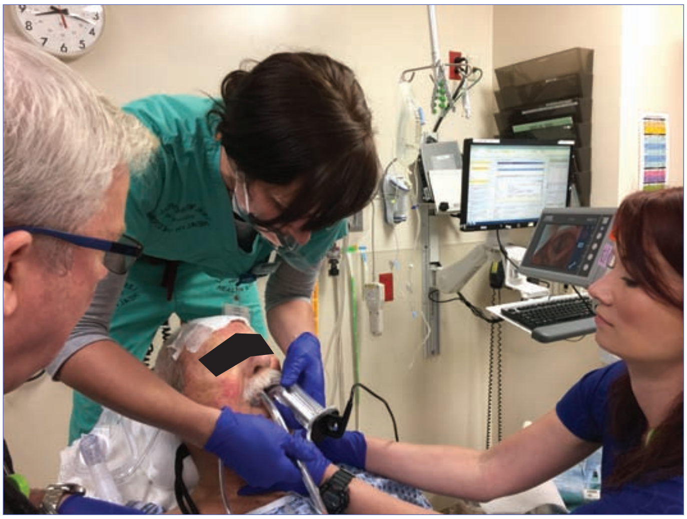

FIGURE 7.5 Head/torso elevation. This has been shown to decrease peri-intubation hypoxia by decreasing compressive atelectasis in the posterior lung zones (alveolar recruitment), improve FRC (especially in the obese patient), and improve diaphragm function (alleviates compression from abdominal contents).

FRC, functional residual capacity.

- In a retrospective 2016 study of 528 patients undergoing emergent ETTI, Khandelwal et al. (2016) found that head-elevated intubation was associated with a decrease in:
  - Hypoxia
    - Head/torso up 6.3%
    - Supine 17%
  - Aspiration
    - Head/torso up 1%
    - Supine 2.3%
  - Decrease in reduced odds of airway-related complications such as hypoxemia and esophageal tube placement
- In a 2017 prospective study of 231 intubations by emergency medicine residents, head/torso elevation showed the following:
  - 19.8% increase in FPS with upright (>45 degrees) compared to incline
    - In fact, for every 5-degree increase in angle, there was an increased likelihood of FPS (OR = 1.11).
  - No change in hypoxia or 5-day mortality
- In a multicenter, randomized ICU study, Semler et al. actually showed:
  - No difference in regard to the median lowest O_2 desaturating between the head/torso-up position compared to the supine
  - A decrease in FPS by 9.2% in the head/torso-up position compared to the supine

Using the head/torso-up position combined with the sniffing position in regard to preoxygenation and intubation makes physiologic sense and, though the literature is not clear in terms of overall benefit, there appears to be a lack of harm.

PATIENT PRESENTATION

Any patient presenting with respiratory distress, altered mental status, or risk for airway obstruction may require advanced airway management such as ETTI. Patients requiring intubation may be categorized as follows:

- Impending or complete airway obstruction—Secondary to infectious, inflammatory, or traumatic insults
- Altered mentation—Absence of protective airway reflexes, inability to tolerate secretions, agitation that may impede diagnostic workup
- Respiratory failure
  - Apnea (e.g., in cardiac arrest)
  - Hypoxia—insufficient oxygenation
  - Hypercapnia—insufficient ventilation

With varying indications for intubation, there are therefore varying patient presentations. Patients with upper airway obstruction may present with stridor, dyspnea, drooling, or a “hot potato”–muffled voice. A patient with a central nervous system insult, such as intoxication, may be at risk for aspiration as they lose the ability to tolerate secretions. Patients in respiratory failure often present with respiratory distress and dyspnea; however, they may also present with undifferentiated altered mental status as hypoxia and hypercapnia in severe forms result in decreased alertness. In some cases, intubation must occur in anticipation of further care—such as a combative patient with polytrauma who must be intubated and sedated in order to be safely transported for CT scan or surgery. The astute clinician should gather objective data regarding airway patency, mental status, and respiratory failure as quickly as possible. A simple assessment of upper airway patency and mental status is achieved by asking the patient their name; if the patient responds correctly and with ease, this indicates the ability to phonate (rules out airway obstruction), as well as to understand simple commands (central nervous system [CNS] insult is less likely). The clinician should also observe the patient's respiratory rate and effort, auscultate for stridor and breath sounds, and monitor oxygen saturation (SpO_2). ***Bedside assessments of oxygenation, ventilation, airway obstruction, and aspiration should guide the decision to intubate rather than reliance on superfluous data such as an arterial blood gas (ABG) test.***

TREATMENT

The mainstay of care for any patient who may be a candidate for ETTI, whether because of respiratory failure, airway obstruction, or lack of airway protection, is to reverse the underlying pathophysiology. If this can be reversed quickly (e.g., with a dose of naloxone for a patient with opioid overdose who presents as hypoxic and apneic, or a patient with anaphylaxis who responds to epinephrine) the need for ETTI may be avoided. However, if the underlying insult cannot be *quickly reversed*, patients may benefit from one of several of the advanced airway management techniques described in the remaining portion of this chapter. The next section discusses the pathophysiology of hypoxia and methods of oxygenation such as BVM and noninvasive positive pressure ventilation (NIPPV). Subsequent sections of the chapter focus on techniques such as placement of extraglottic airways, as well as RSI and ETTI via VAL.

Preoxygenation

Patients who present with respiratory distress and hypoxia should be treated with supplemental oxygen. In addition, patients who appear likely to require ETTI should also be given supplemental oxygen even if they are not hypoxic. This is to increase pulmonary oxygen reserve prior to administering medications that induce apnea during RSI, and therefore decrease the likelihood of hypoxia during the procedure. Ambient air is composed of 78% nitrogen and only 21% oxygen. Prior to intubation, the goal is to increase the patient's SpO_2 to 100%, and to replace pulmonary nitrogen with oxygen. Note that the goal is to "wash out" the 78% nitrogen and replace it with oxygen, thereby building an O_2 bank of nearly 100% O_2. With an adequate oxygen reservoir, otherwise healthy patients may tolerate several minutes of apnea without desaturation to 90% or lower. Once the oxygen reserve is depleted to less than 90%, a more rapid and precipitous decline in SpO_2 is observed (**FIGURE 7.6**). Desaturation to less than 70% imposes a higher risk of dysrhythmia, vascular collapse, hypoxic brain injury, and death.

Anesthesia literature states that having a patient take eight tidal volume (TV) breaths of 100% inspired oxygen (FiO_2) can provide a safe apnea time of over 3 minutes. However, in patients presenting emergently with unknown degrees of pulmonary reserve, it cannot be assumed that this will be sufficient and rarely is.

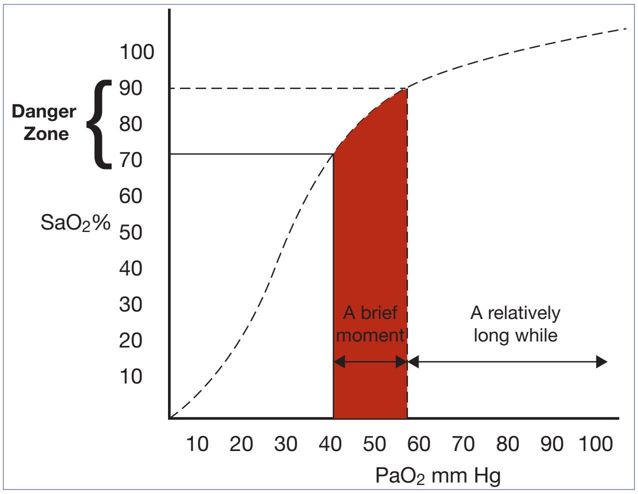

FIGURE 7.6 Oxygen hemoglobin desaturation curve. Note that the O_2 saturation does not decline in a linear manner over time.

The nonrebreather mask (NRB—see Chapter 6) is a common device used to provide supplemental oxygen. The standard therapy is to place a spontaneously breathing patient on NRB at an oxygen flow rate of 15 L/min for a minimum of 3 minutes. This is estimated to generate an FiO_2 fraction of 70%. This may be enough to increase the patient's SpO_2 to 100%; however, it may not sufficiently denitrogenate the distal airways. By opening the flow valve on the wall completely (calibration stops at 15, however the valve can be turned further), one can obtain a flow rate of 30 L/min, thereby increasing the FiO_2 to 0.9. This may in turn more fully denitrogenate the patient, increasing the desired O_2 reservoir.

As stated earlier, during the preoxygenation phase multiple studies have demonstrated the benefit of head/torso elevation or the reverse Trendelenberg positioning. Optimization of positioning decreases atelectasis, increases functional residual capacity (FRC), and increases safe apnea time during RSI. This is especially true in obese patients.

Some patients in hypoxic states may not be able to achieve SpO_2 of 100% with NRB alone. These patients are likely displaying shunt physiology and may benefit from NIPPV and positive end-expiratory pressure (PEEP). *Shunt physiology* refers to venous blood perfusing alveolar capillaries that is not adequately reoxygenated due to poor alveolar ventilation, and therefore insufficiently oxygenated blood is returned to the arterial circulation.

Shunting

- *Shunting* refers to a disease process in which alveoli are not allowing O_2 to diffuse across the alveolar epithelium/pulmonary capillary endothelium secondary to being diseased with:
  - Edema (congestive heart failure [CHF])
  - Pus (pneumonia)
  - Blood (pulmonary hemorrhage)
  - Atelectasis (collapsed alveoli) (**FIGURE 7.7**)

Besides physiologic shunting, another reason patients may not be able to adequately increase and maintain their O_2 saturation despite NRB oxygenation is if their mixed venous O_2 saturation (SvO_2—O_2 saturation of blood returning to the right atrium) is lower than the normal 60% to 80%. This can occur in low cardiac output shock states

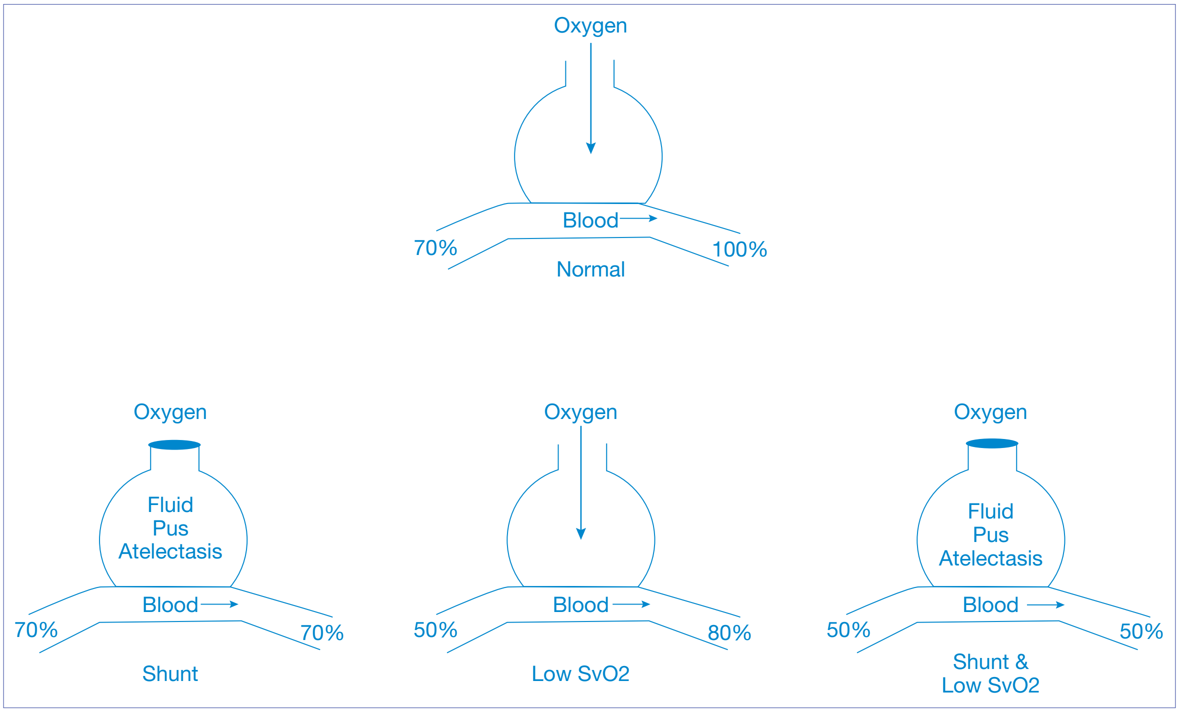

FIGURE 7.7 Physiological pulmonary shunt. Note that the pulmonary blood flow is leaving the alveoli without being adequately oxygenated.

(e.g., hemorrhagic and cardiogenic shock) in which the tissue is attempting to compensate for a decrease in cardiac output by extracting more O_2 than normal. In this scenario, tissue oxygen demand is greater than oxygen supply, thereby causing a decreased SvO_2. ***The answer to this is resuscitation and improvement of patient hemodynamics, especially prior to RSI and ETTI***. RSI medications induce apnea, worsening hypoxia, and hypercarbia (acidosis). ETTI increases intrathoracic pressure, decreasing cardiac preload and cardiac output, which can worsen preexisting hypotension. ***Without adequate resuscitation, patients who are already hypotensive, hypoxic, and/or hypercarbic/acidotic have greater odds of cardiac arrest during RSI and ETTI***.

Hence, the mantra "resuscitate before you intubate."

Noninvasive Positive Pressure Ventilation

- NIPPV with PEEP is the only method used to address patients with physiologic shunting who are in need of preoxygenation above an O_2 saturation of 95%.
- This is because PEEP, by increasing the mean airway pressure, induces alveolar recruitment and alveolar distention, prevents alveolar collapse, and induces the hydrostatic movement of fluid from the alveoli into the interstitium.
- NIPPV can be achieved via
  - BiPAP
  - BVM with a PEEP valve
- There is an abundance of evidence demonstrating the value of NIPPV and PEEP in patients presenting in respiratory distress (**TABLE 7.2**).
- This therapy has been shown to decrease the need for intubation while underlying respiratory pathophysiology is addressed and reversal is attempted.
- If patients are not candidates for BiPAP (see next section) but require preoxygenation via NIPPV prior to ETTI, BVM must be utilized.
- However, there are risks involved inherent to both therapies, such as gastric insufflation and subsequent aspiration.

TABLE 7.2 Hypoxic Critically Ill Patients Displaying Physiologic Shunting—Comparing Preoxygenation With and Without PPV

Oxygen Saturation	PPV Group (%)	Non-PPV Group (%)
Preoxygenation O_2 saturation	98	93
O_2 saturation during apneic time/ETT placement	93	81

ETT, endotracheal tube; PPV, positive-pressure ventilation.

Source: Data from Baillard, C., Fosse, J. P., Sebbane, M., Chanques, G., Vincent, F., Courouble, P., . . . Jaber, S. (2006). Noninvasive ventilation improves preoxygenation before intubation of hypoxic patients. *American Journal of Respiratory and Critical Care Medicine*, *174*, 171–177. https://doi.org/10.1164/rccm.200509-1507oc

BI-LEVEL POSITIVE AIRWAY PRESSURE

While the general use of BiPAP in all patients is described, the reader must realize that, like BVM, BiPAP may be a part of the procedural sequence involved in the preoxygenation of the RSI patient in which shunting is occurring and NIPPV is in order.

Initially developed for patients with sleep apnea and neuromuscular disorders, this noninvasive respiratory modality has become first-line treatment for many patients with acute respiratory distress from both hypoxic (CHF) and hypercapneic (chronic obstructive pulmonary disease [COPD]) respiratory failure. Unlike CHF and COPD, there is a lack of evidence that BIPAP improves the outcome in patients with pneumonia, asthma, or acute respiratory distress syndrome (ARDS).

- Keenan et al. (2003) have shown that in the acute COPD patient, BIPAP has decreased:
  - ETTI by 28% (other studies have shown higher rates)
  - Hospitalization length of stay by 4.57 days

- Other studies have shown a decrease in nosocomial pneumonia from 22% to 8%, with a further decrease in mortality compared to patients treated with ETTI
- In a meta-analysis, Ram et al. reviewed 14 studies evaluating the effect of BIPAP in acute COPD versus standard medical therapy and showed a decrease in
    - Mortality (respiratory rate [RR] = 0.52)
    - Need for intubation (RR = 0.41)
    - Treatment failure (RR = 0.48)

BiPAP should be considered for patients in respiratory distress who are not in extremis and who do not need immediate ETTI (see following text for eligibility). If respiratory status improves with this intervention, the patient may avoid the need for ETTI.

- BiPAP can be thought of as a mechanical form of BVM ventilation for the awake and spontaneously breathing patient.
    - One can think of BIPAP as a more precise, controlled, and cycled form of BVM in which the exact TVs and respiratory rate are set with a peak valve in place and a perfect seal.
    - Composed of two ventilatory cycles/pressures, the difference between these two settings is representative of the given pressure support or TV.
    - It offers the benefit of mechanical ventilation without the risk associated with ETTI.
    - It is used as a tool to transition between invasive mechanical ventilation and spontaneous breathing.
- The main reason for BIPAP is to assist in:
    - Ventilation
        - Inspiratory positive airway pressure (IPAP)
            - Positive pressure delivered with each breath
            - With each breath, either delivered at the set rate or triggered by the patient, the machine delivers an inspiratory pressure, which in turn generates a unique TV based on the patient's lung compliance
            - Always the higher number
    - Oxygenation
        - Expiratory positive airway pressure (EPAP)
            - Analogous to PEEP
                - ❑ During exhalation, PEEP is maintained (EPAP)
            - Keeps alveoli distended
            - Recruits other alveoli
            - Forces fluid from the alveoli into the interstitium
            - Always the lower number
- Just as in BVM, in order to be effective, the BiPAP mask must fit the patient with a proper seal
    - In most facilities, mask fitting and BiPAP setup is commonly conducted by the in-house respiratory therapist; however, clinicians should be familiar with the equipment, setup, and parameters.

- BiPAP parameters that must be selected are:
    - IPAP
    - EPAP
    - RR
        - The minimum number of breaths delivered per minute
        - The patient can trigger the machine for additional breaths
    - Fraction of FiO_2
        - Patients who are hypoxic should be given supplemental FiO_2
            - General range is 40% to 100%

INDICATIONS

- Eligibility:
    - Hypoxic/hypercapnic respiratory failure
        - Without risk of immediate airway compromise
        - Cooperative, awake, and alert patient
        - Spontaneous respiratory drive must be present

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Cardiac arrest
- Partial/full airway obstruction
- Respiratory arrest
    - Bradypnea
    - Apnea
- Foreign body
- Airway obstruction
- Aspiration risk
    - Altered mental status
    - Status epilepticus
    - Copious secretions
    - Vomiting
    - Upper gastrointestinal (GI) bleed
- Anatomic facial abnormalities preventing appropriate mask seal
    - Trauma
    - Burns or other
- Mask discomfort that cannot be relived with adjustments and or sedatives
- Recent esophageal or gastric anastomosis as to avoid inadvertent gastric distention and possible intra-abdominal anastomosis dehiscence
- Pneumothorax
    - Intervention should be considered prior/same time
    - Positive pressure ventilation (PPV) may transition a simple pneumothorax to a tension type

PROCEDURE PREPARATION

- Respiratory therapist (RT) ensures proper mask fitting and ventilatory settings.
- There are various types of masks but the oral–nasal mask is the most common (**FIGURE 7.8**).
    - A nose-only mask is available; however, the patient must keep the mouth closed in order to sustain airway pressures.
- Obtain intravenous (IV) access should the patient require a small dose of sedative in order to tolerate the BiPAP mask (which can be anxiety inducing) or continues to decompensate on BiPAP and require RSI and ETTI.
    - ABG/venous blood gas (VBG) may be obtained as *adjunctive* data.

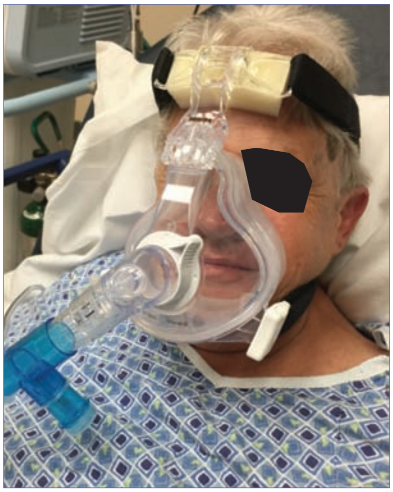
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FIGURE 7.8 BIPAP oral–nasal mask. BIPAP, bi-level positive airway pressure.

PROCEDURE

- Respiratory therapist should be at the patient's bedside assisting in adjusting ventilatory settings and ensuring proper mask size.
- Apply the mask and straps to the patient.
    - You should be able to place two fingers easily between the straps and the patient's head; the mask should not extend over the chin.
    - Assess for patient comfort and air leak.
    - If the mask continues to be uncomfortable or there are large air leaks, replace the mask with one of a different size.
- The silicon cushion forms a seal around the nose and the mouth.
- Typically, use of the smallest mask that can provide a proper fit is the most effective.
- Although the nasal mask induces less claustrophobia, the seal is often lost as patients may have difficulty keeping the mouth closed.
- Patient may require a small dose of a sedative to ensure mask comfort as the mask often induces some anxiety/claustrophobia.

- Apply appropriate parameter settings.
    - IPAP
        - Start at 10 to 15 cm of water
    - EPAP
        - Start at 5 cm of water
    - RR
    - FiO_2

POSTPROCEDURE CONSIDERATIONS

- Continually reassess the patient for changes in clinical status with regard to
    - Mental status
    - Work of breathing
        - RR
        - SpO_2
        - ABG/VBG to be used as *supportive* evidence as to procedure effectiveness
- Persistently hypercapnic
    - Increase the IPAP by increments of 2 cm of water in order to increase the TV.
- Persistently hypoxic
    - Increase EPAP by increments of 2 cm of water.
        - If this is done one may have to increase the IPAP also in order to maintain a constant TV (pressure support).
    - Increase FiO_2
- If patients continue to have persistent hypoxia, hypercapnia, work of breathing, or deterioration in mental status, consider RSI and ETTI.
    - In general, trials of 1 to 2 hours are useful to determine whether the patient is improving or needs more advanced intervention (i.e., ETTI).
- Predictions of success include:
    - Clinical improvement in respiratory status
    - Decrease in $PaCO_2$ >8 mmHg
    - Improvement of pH >0.06

COMPLICATIONS

- Skin pressure injuries from overly tight-fitting mask
- Anxiety/claustrophobia—May be ameoliorated by cautious use of sedatives
- Gastric distention: Avoid IPAP >20 cm of water
    - Lower esophageal sphincter (LES) opening threshold

BVM VENTILATION

BACKGROUND

While the general use in all patients is described, the reader must realize that, like BIPAP, BVM ventilation may be a part of the procedural sequence involved in the preoxygenation of the RSI patient in which shunting is occurring and NIPPV is needed.

The BVM (**FIGURE 7.9**) is the second method of NIPPV to be described. BVM skills are imperative to anyone working with critically ill patients. These self-inflating bags have a one-way valve between the reservoir and the bag on the distal end and a similar valve in the proximal end between the bag and the mask, with a manometer, which opens only via:

- Squeezing the bag
- Negative inspiratory pressure generated by the patient (if there is an appropriate mask seal)

BVM can be applied to patients who are:

- Spontaneously breathing yet require ventilatory support
    - “Bagging with the patient” means the clinician squeezes the bag as the patient breathes
    - Example is an asthmatic patient in respiratory distress who is spontaneously breathing; this patient may be “bagged with” as therapeutic medications are administered

- Apneic and require full ventilatory support
  - "Bagging the patient"
    - Example is an apneic patient who had an opioid overdose; may be fully "bagged" until naloxone takes effect
    - Other example includes the patient in cardiac arrest
    - RSI (see section that follows)

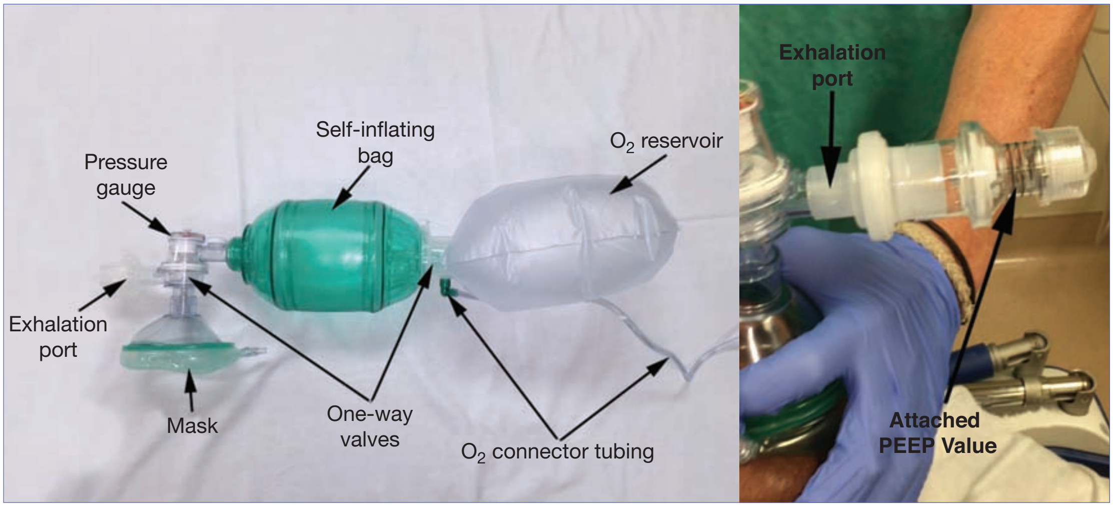
Self-inflating bag
Pressure gauge
O$_2$ reservoir
Exhalation port
Mask
One-way valves
O$_2$ connector tubing
Exhalation port
Attached PEEP Value

FIGURE 7.9 Anatomy of bag-valve mask. Note PEEP valve attached to exhalation port. PEEP, positive end-expiratory pressure.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Absolute Contraindications

- Inability to form and/or maintain a mask/face seal
- Lack of airway patency

Relative Contraindications

- Predictors of difficult BVM
  - Micrognathia
  - Facial trauma
  - Facial hair
    - Beards may inhibit proper seal
    - Can be improved with lubrication or an adhesive dressing over the beard to matt down the facial hair to form a better seal
    - Edentulous patients
      - Dentures, if present, should be left in place while bagging and taken out if intubating; if no dentures are present, an airway adjunct (oropharyngeal airway [OPA]) or nasopharyngeal airway (NPA; see Chapter 6) can be used.
    - Obesity
    - Elderly
    - History of obstructive sleep apnea
    - Limited neck extension
    - Limited mouth opening

SPECIAL CONSIDERATIONS

- Use of an airway conduit is highly recommended (see Chapter 6).
- Authors strongly recommend the use of an NPA over an OPA because the former:
  - Induces no gagging
  - Is easier to place
  - Leaves the oral cavity unoccupied
  - Can be left in place during ETTI
- Have a Yankauer suction catheter at arm's reach.
- Use a roll or ramp under the shoulders of obese patients.
- Pull the mandible upward rather than pushing the mask down.

PROCEDURE PREPARATION

- Call for assistance
- Elevate head/torso
- Perform jaw thrust
- Ensure proper patient positioning ("sniffing position" as previously described) and or jaw thrust maneuver
- Gather appropriate equipment (**FIGURE 7.10**):
  - BVM with PEEP valve connected to airway source with bag fully inflated
  - NPA
  - Suction

PROCEDURE

NPA should be placed (see Chapter 6) and the head/torso should be elevated. Mask should be placed with the pointed area over the nasal bridge taking care not to cover the patient's eyes nor extend beyond the chin. Attach tubing to high-flow O_2 at minimum 15 L/min.

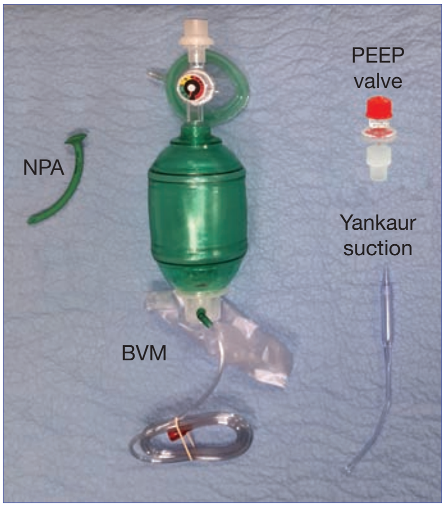

FIGURE 7.10 BVM, NPA, Yankauer, and PEEP valve.

BVM, bag-valve mask; NPA, nasopharyngeal airway; PEEP, positive end-expiratory pressure

One-Handed Method

- "C-E" grip method (**FIGURE 7.11A**).
- Thumb and index finger exert pressure on the proximal and inferior mask, respectively, while the third through fifth fingers grasp mandible body/angle and perform a jaw thrust.
  - Do not clasp the submandibular soft tissue as this may induce inadvertent tongue occlusion.
- Though this is touted as the classic method, only use this practice if there are not enough personnel available to perform the two-hand method, as one cannot reliably maintain a seal with one hand as this is difficult and fatiguing.

Two-Handed Method

- Thenar eminence method (**FIGURE 7.11B**).
- Place both thenar eminences on each side of the mask parallel to the stretcher and apply downward force, while the second to fifth fingers grasp the mandible body/angle and perform a bilateral jaw thrust. This creates a more reliable seal with considerably less effort.
- Two-handed method is recommended over the C-E grip by the American Heart Association (AHA) guidelines on cardiopulmonary resuscitation.
- As one clinician ensures the mask's seal, a second clinician squeezes the bag.
  - Deliver the minimum squeeze necessary to generate a visible chest rise, without generating positive pressure greater than 20 cm of water; this may reduce risk of LES opening, gastric distention, and aspiration.
  - The LES opens at 25 cm of water, so maintain pressures below this upon insufflation.
- Deliver eight to 10 breaths per minute.
  - Eight breaths per minute delivered with each squeeze; a squeeze should have a 2-second duration.
  - Rapid inspiratory times increase peak airway pressures and risk gastric distention and aspiration.

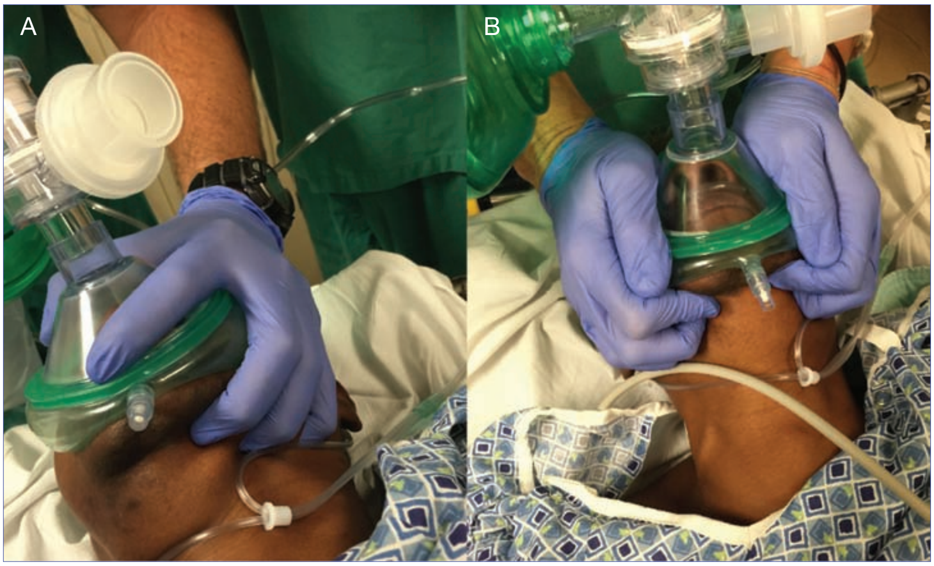

FIGURE 7.11 (A) One- and (B) two-handed bag-valve mask technique.

- TVs ≤6 mL/kg (500 mL)
- Even at an FiO_2 of 0.5, only 500 mL/min is needed to maintain O_2 saturation.
- Healthy patients consume 250 mL/min of O_2

POSTPROCEDURE CONSIDERATIONS

- Continually reassess for proper seal and airway patency.
- Consider next step in airway management:
  - ETT
  - Supraglottic device

COMPLICATIONS

- Inability to ventilate (consider advanced airway device)
- Gastric insufflation, aspiration; have suction readily available and consider placing advanced airway if necessary
- As with any positive pressure ventilation, increased intrathoracic pressure reduces cardiac preload and therefore cardiac output; this may result in hypotension

Supraglottic Airway

Supraglottic devices, also known as "intermediate airways," are devices that are placed within the upper airway to serve as a conduit for gas delivery to the glottic opening. However, the devices themselves do not pass through the glottis and therefore cannot be defined as "definitive airways." This text focuses on one of the most common types of supraglottic airway (SGA) devices, the i-gel. However, advanced airway providers should familiarize themselves with additional SGAs such as the laryngeal mask airway (LMA; **FIGURE 7.12**).

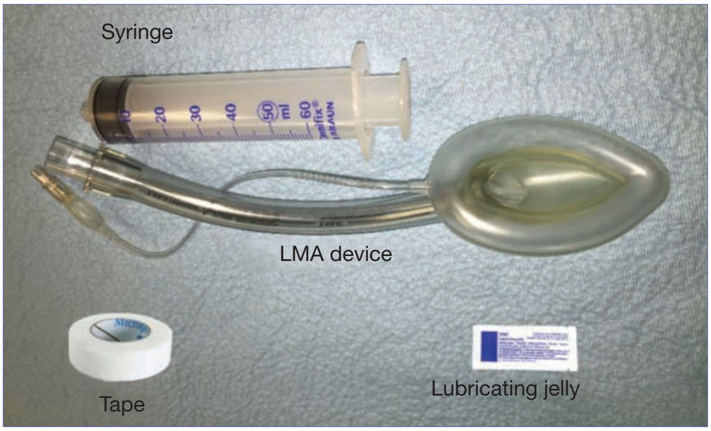

FIGURE 7.12 LMA device with adjunct supplies. LMA, laryngeal mask airway.

I-GEL

BACKGROUND

This intermediate airway device is increasingly used not only by anesthesiologists, but also by emergency and prehospital clinicians. The AHA states that this is an acceptable device for use by nonexperts in ETTI when performing advanced airway maneuvers. One can think of this as a small internal BVM, bypassing upper airway soft tissue obstructions, and overlying the supraglottic area.

The device is a flexible airway tube with a noninflatable cuff filled with an elastomer gel. The proximal end has a standard connector that attaches to any ventilating equipment (BVM, ventilator).

INDICATIONS

- Rescue airway device for failed BVMs
- Rescue airway device for failed ETTIs
  - Should be within arm's reach when initiating ETTI
- Used by advanced airway providers with inadequate skills in terms of ETTI
- Used by the resuscitated prehospital cardiac arrest patient in need of an advanced airway
  - AHA calls for an advanced airway in such patients, which, depending upon training and equipment, could be:
    - ETT
    - SGA

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- This is a blind insertion device and as such its use is not recommended in cases with potential foreign bodies in the upper airway (**FIGURE 7.13**) or an other upper airway obstruction.

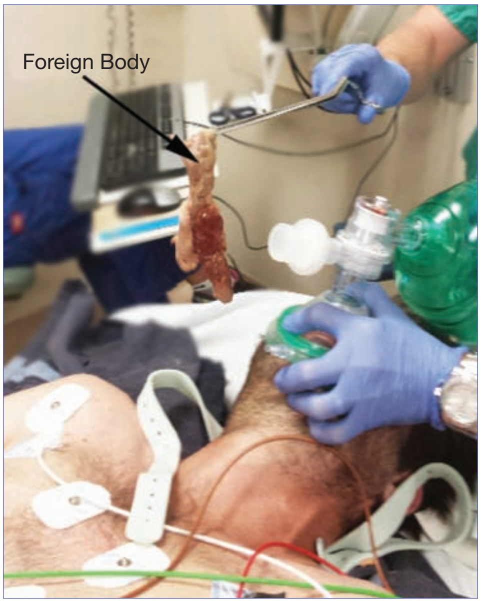

FIGURE 7.13 Upper-airway foreign body retrieved after prehospital blind LMA insertion. LMA, laryngeal mask airway.

SPECIAL CONSIDERATIONS

- Less gastric distention (aspiration) occurs than in BVM as it requires less pressure to achieve effective ventilation.
  - Stone et al. (1998) have shown that the incidence of gastric regurgitation was lower when the SGA was used in favor of BVM before ETTI.
  - However, as it is not a protected airway, the risk of aspiration is still greater than that of ETTI. It does offer protection from secretions produced above the device.
- Offers ease of placement by clinicians with limited experience in advanced airway management.
- Ease of placement during cardiac arrest:
  - There is minimal/no chest compression interruptions, which allows cardiac perfusion pressure to be maintained.
  - The 2010 AHA guidelines changed the rules for the cardiac arrest patient from an airway, breathing, circulation (ABC) hierarchy to a CAB one; circulation is attended to first–before airway and breathing.
- Has higher first–time success rate than ETTI.
- Is easier to ventilate compared with BVM.
- Bypasses tongue and pharyngeal soft tissue and is closer to the glottis.
- Placement requires no head movement.
- Requires one person as opposed to BVM, which ideally requires two.

PROCEDURE PREPARATION

- Gather equipment: i-gels usually come in a prepackaged container (**FIGURE 7.14**).
- Lubricate the cuff surface on all sides.

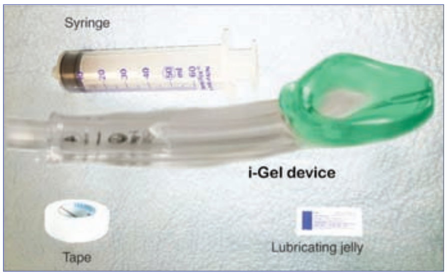

FIGURE 7.14 i-gel setup.

PROCEDURE

- Stand at the head of the bed, perform a jaw thrust to open the airway; the patient should be in the "sniffing" position with head extended and neck flexed already.
- Grasp the lubricated i-gel firmly along the integrated bite block.
- Position the device so that the i-gel cuff outlet is facing toward the chin of the patient.
- The chin should be gently pressed down before proceeding to insert the i-gel.
- Introduce the leading soft tip into the mouth of the patient, moving toward the hard palate (**FIGURE 7.15**).
- Glide the device downward and backward along the hard palate with a continuous but gentle push until resistance is felt.
- The device is in its final resting position when the cuff is beyond the inferior/posterior tongue at the laryngeal inlet (hypopharynx; **FIGURE 7.16**).
- Connect the device to a positive pressure system.
- Secure with formal strap or tape.

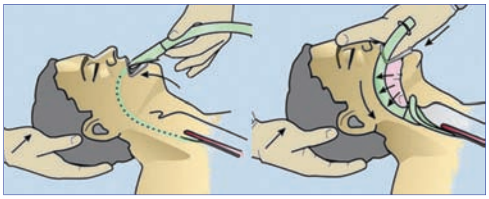

FIGURE 7.15 i-gel placement.

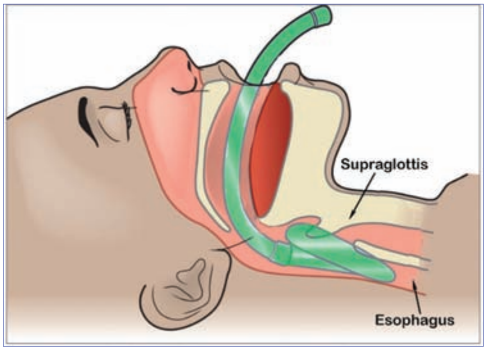

FIGURE 7.16 i-gel proper supraglottic position. Note that the distal tip of the cuff sits partially on the esophagus, while its anterior surface sits in the supraglottic area. Note the trachea and esophagus are not isolated from each other.

POSTPROCEDURE CONSIDERATIONS

- As in ETTI (see text that follows), capnography is the gold standard for successful placement.
- Unlike ETTI, auscultation over the neck trumps the lateral chest area for assessment of proper placement.
- If this fails, remove the device, and replace it with larger sized device.

COMPLICATIONS

- Improper placement can occur and result in a poor seal or obstruction of air flow.
  - In a meta-analysis, Hubble et al. (2010) have shown that the common level of obstruction is at the oropharynx, as the epiglottis folds down upon itself, or the tongue/pharyngeal soft tissue is pushed into the airway.
  - If this occurs, withdraw the device approximately 6 cm and readvance.
- Gastric distention, regurgitation, and aspiration can occur.
  - Only provides partial occlusion of the esophagus and does not isolate the trachea
- Upper airway/dental trauma can occur.
- Laryngospasm may occur if the cuff tip comes into contact with the glottis or if aspiration occurs.

DEFINITIVE AIRWAY MANAGEMENT

The airway interventions listed previously do not constitute definitive airway management, which is defined as an airway device with an inflated cuff placed in the trachea (i.e., below the vocal cords). Anything short of this is a temporizing technique, which may prevent or delay the need for intubation (e.g., BiPAP management in a COPD exacerbation), or a placeholder (e.g., the SGA during cardiac arrest). If the COPD patient, for example, continues to deteriorate, definitive airway management must take place. If the resuscitation of the patient who suffered a cardiac arrest is successful, the SGA should be exchanged for a protected airway, but only after resuscitation. In the following text we describe the controlled technique of RSI, ETTI with VAL, and postintubation considerations.

RAPID SEQUENCE INTUBATION

BACKGROUND

The ultimate airway management goal for patients requiring intubation is to place the ETT quickly into the trachea, without inducing iatrogenic hypoxia. In addition, patients presenting emergently usually have nonfasting stomachs, posing an aspiration risk. These patients are inherently different than those prepared for the operating room (OR) undergoing elective intubation who have fasted for a minimum of 8 hours and therefore have a negligible risk for aspiration. Also, unlike the elective OR patients, emergent dyspnea patients by definition have limited pulmonary reserve secondary to acute and/or acute on chronic pulmonary pathology with minimal parenchymal reserve. In order to reduce the risk of hypoxia and aspiration from gastric distension, the practice of RSI was developed.

It is best to conceptualize RSI as a procedure in itself. This procedure's end goal is to replace the 78% nitrogen from the alveoli and replace it with 100% O_2, thereby allowing this "O_2 bank" to provide a safe and prolonged apnea period after such rapid-acting and potent induction and paralytic agents are given.

In its simplest form, this "procedure" constitutes delivery of rapidly acting sedating and neuromuscular blocking (paralyzing) medications after adequate preoxygenation has been achieved for the reasons given earlier. During this swift transformation from the conscious to the unconscious and paralyzed state, glottic visualization is obtained and a cuffed ETT is promptly placed. PPV is minimized during the procedure of RSI in order to avoid gastric insufflation and potential pulmonary aspiration. RSI has been the mainstay of emergent ETTI for decades and continues to be the standard of care.

Indications

- Patients with indication for ETTI (see "Patient Presentation" section), who do not require a "crash airway" (i.e. patients with cardiac arrest)

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Patient with difficult airway may require intubation without use of a paralytic agent. The classic example of this is the awake fiber-optic intubation of patients with upper airway obstruction such as angioedema or Ludwig's angina. A description of awake fiber-optic intubation is beyond the scope of this chapter.
- Patients in cardiac arrest are obtunded and have flaccid musculature; these patients do not require RSI medications.
- Note that the following are predictors of potentially difficult intubations:
  - Facial trauma
  - Neck tumors
  - Burns
  - Angioedema
  - Infection
    - Pharyngeal
    - Laryngeal
    - Soft tissue
- Classification
  - A high Mallampati score (Class III or IV) is associated with more difficult intubation.
    - Class I: Soft palate, uvula, fauces, pillars visible
    - Class II: Soft palate, uvula, fauces visible
    - Class III: Soft palate, base of uvula visible
    - Class IV: Only hard palate visible

PROCEDURE PREPARATION

- Recruit necessary personnel; obtain IV access
- Gather all airway equipment to the bedside

- Apply monitoring devices:
  - $ETCO_2$
  - Cardiac monitor
  - SpO_2
  - Blood pressure (BP) cuff
    - Should ideally be applied to the arm contralateral to the SpO_2 monitor and IV
    - When the cuff inflates it interrupts blood flow, thereby inhibiting medication delivery and falsely lowering SpO_2
- Yankauer catheter with wall suction
- Nasal cannula (NC)
  - Should be placed on all patients undergoing RSI
  - Place under NRB, BVM, or BIPAP

Apneic Oxygenation

During the apneic phase of RSI, pulmonary blood flow is still occurring and, because of this, O_2 is continually being diffused out of the alveolar epithelium and into the capillary endothelium, attaching itself to circulating hemoglobin at a rate of 250 mL/min. This creates an O_2 concentration gradient from the alveoli to the pulmonary capillary bed and, in doing so, likewise creates an O_2 concentration gradient between the more proximal airways and the alveoli. After the patient is paralyzed, there is flow and movement of O_2 down these concentration gradients, as the alveoli are somewhat subatmospheric and a mass flow of gas moves from the proximal airways into the alveoli. In a 2017 meta-analysis of nine studies (including four randomized control trials), Pavlov et al. (2017) found that apneic oxygenation reduced the relative risk of clinically significant hypoxia ($SpO_2 < 90\%$) by 30% during emergency intubation.

- Apneic oxygenation can be performed by applying a nasal cannula at minimum 15 L/min to the patient during RSI.
- Gather essential supplies
  - NRB
  - BVM/BiPAP
    - When needed for shunt physiology, that is, failure to adequately oxygenate
    - In a recent *New England Journal of Medicine* (*NEJM*) article, Casey et al. (2019) have questioned the avoidance of using NIPPV (BVM) in RSI scenarios without shunting.
    - See next section
  - ETT with stylet
  - VAL equipment
  - Rescue device such as an SGA
- Position patient with head/torso elevated
- Begin preoxygenation
  - NC at 6L/min—apneic oxygenation
    - Noxious to the nasal mucosa above this rate
    - Upon paralysis, increase NC to 15L/min
  - NRB at 30L/min over the NC
  - In some cases, patients will not be adequately preoxygenated (O_2 saturation ≥93%–95%) with NRB alone.
    - These patients are likely in critical states of shock or displaying shunt physiology.
  - For patients in shock states, make sure the patient is adequately resuscitated prior to administration of RSI medications.
    - ***Resuscitate before you intubate.***
      - Detailed management of patients in shock is beyond the scope of this chapter.
  - Consider trial of NIPPV if patient is an appropriate candidate and the need for ETTI is not emergent.

Consider Delayed Sequence Intubation

- Indicated when patients do not demonstrate anticipated response to preoxygenation.
- If one cannot preoxygenate for 3 minutes to the point of full denitrogenation, then there will be little, if any, safe apnea time.
- Think of this technique as a conscious sedation procedure and the procedure to be performed is proper preoxygenation.
- It is accomplished by the clinician delivering the sedative *without* simultaneous administration of the paralytic agent.

- Ketamine is the ideal agent at 1.5 mg/kg IV or 5 mg/kg if an IV has yet to be established.
- A 2015 multicenter observational trial of 64 patients demonstrated that delayed sequence intubation (DSI) sedation with ketamine is safe and effective for preoxygenation and should be considered in patients who cannot cooperate with normal preoxygenation.
- A dissociative anesthetic maintains protective airway reflexes.
- Preoxygenation can now occur for 3 minutes.
- Paralytic agent can now be administered and RSI/VAL can be performed.
- The use of BVM PPV is controversial. RSI classically mandates that BVM PPV is not conducted to avoid the risk of gastric distention; however, recent literature has challenged this.
  - Casey et al. (2019) conducted a landmark multicenter randomized control trial in which 401 critically ill adults undergoing ETTI were randomized to BVM during the apneic phase of RSI or the standard of care (no BVM).
  - Patients who received BVM PPV during RSI had significantly greater median lowest SpO_2 (96% vs 93%), and more important, there were no differences in aspiration events (actually more aspirations in the "no baging" arm).
  - It is important to note, however, that patients at high risk for aspiration were excluded and bagging was conducted using the two-handed method with minimal volumes for visible chest rise.
  - Advocates include The Difficult Airway Society Guidelines in the United Kingdom, which supports manual ventilation during rapid-sequence induction in the ICU.
  - Though this opens further discussion on the debate of BVM after induction/paralysis, please note that this is a single article and was based in an ICU setting.
  - Also, it was underpowered in regard to clarifying aspiration and, being in an ICU setting, perhaps patients' stomachs were relatively empty compared to patients presenting in the ED.
  - In this trial, chest movement was used to confirm the effectiveness of bag-mask ventilation; this is an insensitive measure; capnography is more appropriate because it provides objective confirmation of the effectiveness of ventilation in real time.
  - The results of this trial suggest that BVM is effective and safe in many patients who were previously not receiving such, although the efficacy and safety are uncertain in patients who are at high risk for aspiration.
  - The authors of this chapter conclude that BVM after induction and paralysis needs to be studied further in the ED setting.

PROCEDURE

- Assess for contraindications to RSI medications; select appropriate medications and doses.
- Administer induction and paralytic agents sequentially via rapid IV push.
  - One attempt to transition the awake patient as quickly as possible with extremely potent and rapidly acting medications to an unconscious and paralyzed state
  - Induction agents should be administered first (**TABLE 7.3**)
    - Ketamine
    - Etomidate
    - Propofol
  - Paralytic agents (**TABLE 7.4**)
    - Rocuronium
    - Succinylcholine
- Optimal patient position
  - Head/torso up
  - Sniffing position
- Obtain glottic visualization by VAL (see next section), and pass the ETT through glottic opening
- Remove the stylet, inflate the balloon, and attach to BVM
- Ideally, check for correct tracheal position before bagging the patient
  - Point-of-care ultrasound (POCUS)
  - End-tidal carbon dioxide ($ETCO_2$)
  - Secure ETT using a commercial device or tape.

Medication Selection

The debate regarding the ideal paralytic agent to use for RSI is ongoing and controversial. The ideal agent should be rapid in onset, short in duration, with a limited side-effect profile. It is unfortunate that neither of the two listed satisfies

TABLE 7.3 RSI Induction Medications

Induction Agent	Dose	Onset	Duration	Advantages	Cautions
Ketamine	1.5–2.0 mg/kg IV push (not to exceed 0.5 mg/kg/min); normal adult dose about 100 mg	1 minute	10–20 minutes	■ Induces catecholamine release–beneficial in hemodynamically unstable patient ■ Bronchodilator– preferred agent for patients with status asthmaticus ■ May possess neuroprotective effects as it increases CPP without increasing the ICP	■ ICP elevation appears to be based more on dogma than literature—in fact, ketamine may have neuroprotective properties ■ Hallucinations, emergence delirium—more evident when used for conscious sedation
Etomidate	0.3 mg/kg IV push; normal adult dose about 20 mg	15–45 seconds	3–12 minutes	■ Hemodynamically neutral–beneficial in patients with tenuously low blood pressure ■ Decreases ICP—useful in patients with elevated ICP	■ Adrenal suppression—controversy in literature; consider avoiding in patients with septic shock ■ Myoclonus—not clinically significant ■ Does not provide analgesia
Propofol	1.5 mg/kg IV push; normal adult dose about 100 mg	15–45 seconds	5–10 minutes	■ Decreases ICP—useful in patients with elevated ICP	■ Causes hypotension—avoid in hemodynamically compromised patients

CPP, cerebral perfusion pressure; ICP, intracranial pressure; IV, intravenous; RSI, rapid sequence intubation.

TABLE 7.4 RSI Paralytic Medications

Paralytic Agent	Dose	Onset	Duration	Advantages	Cautions
Rocuronium	1.0–1.5 mg/kg IV push; normal adult dose about 100 mg	1 minute	45 minutes	■ Reversal agent—Sugammadex 16 mg/kg ■ Nondepolarizing NMB ■ Minimal effect on hemodynamics ■ Low incidence of histamine release (0.8%)	■ Duration prolonged with hepatic impairment
Succinylcholine	1.5 mg/kg normal adult dose about 100 mg	45 seconds	6–10 minutes	■ Depolarizing agent ■ Rapid onset and short duration of action	Contraindications: ■ History of malignant hyperthermia ■ Pre-existing hyperkalemia ■ Hyperkalemia predisposition: ➢ >5 days postburn injury ➢ >5 days—6 months after spinal cord injury/stroke ➢ Crush injury/ rhabdomyolysis ➢ Congenital myopathy Adverse effects: ■ Fasciculations; may increase ICP ■ Bradycardia with repeat doses

ICP, intracranial pressure; IV, intravenous; NMB, neuromuscular blockade.

all of these criteria as succinylcholine has a considerable side effect profile, whereas rocuronium has a slower onset and longer duration of action. A 2015 Cochrane review reported that succinylcholine resulted in superior intubating conditions; however, the studies included in this review were taken largely from anesthesia and OR literature, and did not focus on patient-centered outcomes. A 2018 observational analysis from the aforementioned international NEAR database concluded that there were no differences in FPS, nor adverse outcomes (including cardiac arrest) between 2,275 intubations conducted with succinylcholine and 1,800 conducted with rocuronium.

Sugammadex

- Mechanism of action is via binding/encapsulating the circulating nondepolarizing neuromuscular blocking agent; secondary to this, it promotes dissociation of the depolarizing neuromuscular blocking agent from the neuromuscular junction by creating a concentration gradient.
- In a randomized prospective study of 60 patients, Sorensen et al. observed how rapidly spontaneous ventilation was reestablished after RSI with either succinylcholine or rocuronium followed by 16 mg/kg sugammadex.
  - Spontaneous ventilation returned 406 seconds after succinylcholine, compared to 216 seconds after rocuroniumnd–sugammadex.
  - The time to T1 (first twitch of the train of four) 90% was 518 seconds with succinylcholine and 168 seconds with rocuroniumnd–sugammadex.
  - The authors concluded that RSI with rocuronium–sugammadex combination allowed earlier spontaneous ventilation than with succinylcholine.
- However, sugammadex administration does not guarantee return of spontaneous ventilation or easy mask ventilation and effective oxygenation, despite the patient regaining motor strength.
- The inappropriateness of using rocuronium in the case of a predicted difficult airway is demonstrated by several case reports in which sugammadex was not helpful in obtaining effective oxygenation following failed intubation.
  - This rapid reversal of neuromuscular block has led to sugammadex being suggested as a rescue drug in a can't-intubate/can't- ventilate scenario after administration of rocuronium.
  - Curtis et al. (2010) and Kyle et al. (2012) separately report similar cases of the use of sugammadex in a can't-intubate/can't- ventilate scenario, which highlights the rapid reversal of neuromuscular block with sugammadex.
  - However, as in the case presentations, this did not/does not translate into reversing the offending airway obstruction and perhaps it may make it worse via instrumentation of an already compromised airway.
  - Authors concluded that although sugammadex does indeed reverse the paralysis of neuromuscular blocking agents, it does not necessarily ensure ventilation will be restored.
- If a difficult airway is suspected, fiber-optic intubation while the patient is awake appears to be a safer alternative to induction with a paralytic agent.

VIDEO-ASSISTED LARYNGOSCOPY

BACKGROUND

ETTI is required in any situation in which definitive control of the airway is needed. Intubation may be accomplished using two types of laryngoscope: direct or video. The typical video-assisted laryngoscope has a light and an optic magnifier. The GlideScope model has a hyperangulated 60-degree angle on its blade allowing it to negotiate the almost 90-degree angle between the OA and LA; direct laryngoscopes have a 30-degree angle on their curved blades (**FIGURE 7.17**). Indications for ETTI are reiterated here:

- Impending or complete airway obstruction
  - Itubate sooner than later
    - Infection
    - Inflammation
    - Traumatic insults
- Altered mentation (absence of protective airway reflexes, inability to tolerate secretions, agitation that may impede diagnostic work up of a potentially critical patient)
- Apnea
- Hypoxia
- Hypercapnea
- Postcardiac arrest resuscitation

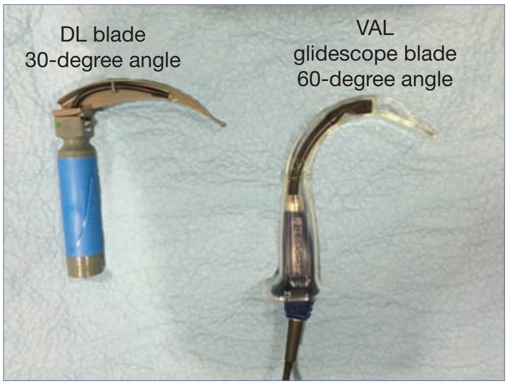

FIGURE 7.17 Direct laryngoscopy blade versus VAL GlideScope blades.

DL, direct laryngoscopy; VAL, video-assisted laryngoscopy.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- None
- Exception in patients with advanced directives indicating "do not intubate"
- Always think "worse first" and, in this regard, assess for the potential difficult intubation:
  - All patients undergoing ETTI should be assessed for airway difficulty.
  - There is no single assessment used to determine whether patient will have a difficult airway.
  - Assessments should be used in conjunction with one another to form the clinical picture of the potentially difficult airway.
  - Examples of upper airway obstruction/narrowing:
    - Upper airway mass/tumor
    - Inhalational injuries from burn
    - Angioedema
    - Upper airway soft tissue infection (e.g. Ludwig's angina)
    - Expanding neck hematoma
    - Trismus, short thyromental distance, micrognathia
    - Obesity
    - Poor neck mobility, cervical spine immobilization in trauma patients
    - Mallampati classification
      - A high Mallampati score (Class III or IV) is associated with more difficult intubation as well as a higher incidence of sleep apnea.
    - Airway secretions: Blood (trauma, upper GI bleed, pulmonary hemorrhage), emesis, saliva

PROCEDURE PREPARATION

- As indicated previously, ensure the following is in place:
  - Cardiac monitor
  - $ETCO_2$ monitor
    - ***One will see a change in this important monitoring device well before that of a pulse oximeter.***
  - Pulse oximeter
  - At least one IV
- Perform the procedure of preoxygenation.
- Apneic oxygenation must be provided.
- Patient should be in head/torso-up position if able to tolerate during preoxygenation.
  - Reposition to supine sniffing positioning while maximizing the three airway axes previously described after administration of RSI medications or
  - Consider further head/torso elevation while performing VAL (see **FIGURE 7.5**)
  - RT should observe the monitor and report any changes immediately
- RSI medications should be in syringes and appropriate dosing ensured and should be given via IV push followed by flush of normal saline.

- The height of the bed should be at the lower sternum of the laryngoscopist; if utilizing the head/torso-up position, use a stool.
- *Back-up airway equipment needs to be available within arm's reach in case of equipment failure, and one must always assume the procedure may fail.*
  - *At minimum, a backup plan needs to be considered and the necessary equipment for this plan should be at the bedside (**FIGURE 7.18**).*

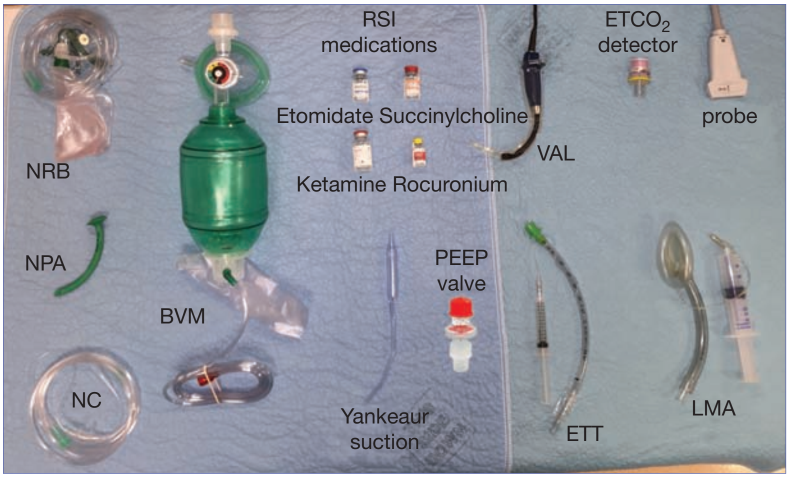

FIGURE 7.18 Equipment required for the procedures of preoxygenation, RSI, and VAL, including backup airway equipment. These items should always be literally within an arm's reach.

BVM, bag-valve mask; ETCO$_2$, end-tidal carbon dioxide; ETT, endotracheal tube; LMA, laryngeal mask airway; NC, nasal cannula; NPA, nasopharyngeal airway; NRB, nonrebreather mask; PEEP, positive end-expiratory pressure; RSI, rapid sequence intubation; VAL, video-assisted laryngoscopy.

Equipment

- Personal protective equipment:
  - Gloves
  - Face mask with eye shield
- Yankauer suction within reach and turned on
- VAL equipment at bedside (see **FIGURE 7.17**)
- All equipment must be close to the head of the bed; intubator should have unobstructed view of the screen, which should be on the right side of the bed in the line of sight.
- VAL should have proper blade size preattached:
  - Size 2 in pediatric patients 2–10 kg
  - Size 3 for small adults
  - Size 4 for large adults
- ETT with rigid stylet in place:
  - Ensure the tip of the stylet does not extend past the distal tip of the ETT.
  - Manufacturer provides a preformed reusable rigid stylet with optimal curvature.
  - A malleable stylet with a 60-degree curve can be substituted.
    - This is to mirror the hyperangulated GlidePEScope blade and allows for easier trajectory from mouth to glottis.
- ETT selection: Choose the largest ETT possible to pass through the glottic opening:
  - Size 8 in most adults
  - Pediatric size:
    - 0–6 months
      - 3.0 mm
    - 6–12 months
      - 3.5 mm
    - >12 months
      - ETT size can be estimated using the following equations:

        Uncuffed ETT: (Age in years/4) + 4
        Cuffed ETT: (Age in years/4) + 3.5

- Check the cuff for leaks with insufflation of air and then remove all air with 10-cc syringe.
- Have the next smaller size ETT ready and prepared if needed.
- Have BVM attached to high-flow O_2 source and in-line $ETCO_2$ monitor.
- Have NPA (preferably)/OPA should intubation fail and BVM ventilation be required to reoxygenate.
- Have commercial endotracheal tube holder/tape/bite block.
- ETT confirmation devices:
    - Capnography
    - Stethoscope
    - POCUS
    - Chest x-ray (CXR)

PROCEDURE

- Initiate only after proper positioning, preoxygenation, and apneic oxygenation are fully implemented as described previously.
- Hold the VAL in the left hand with the blade facing down.
- Unless the monitor is part of the blade itself, it should be on the side of the bed in the line of vision of the operator; ensure the monitor is illuminated (**FIGURE 7.19**).
- Use ETT with rigid stylet in place.
    - Ensure the tip of the stylet does not extend past the distal tip of the ETT.
- Open patient's mouth with your right hand using the scissor technique.
    - Place the thumb and index finger of the right hand into the right side of the patient's mouth.
    - Place the index finger on the patient's upper teeth and the thumb on the lower teeth; using a scissor-like movement, open the mouth *as wide as possible* (**FIGURE 7.20**).

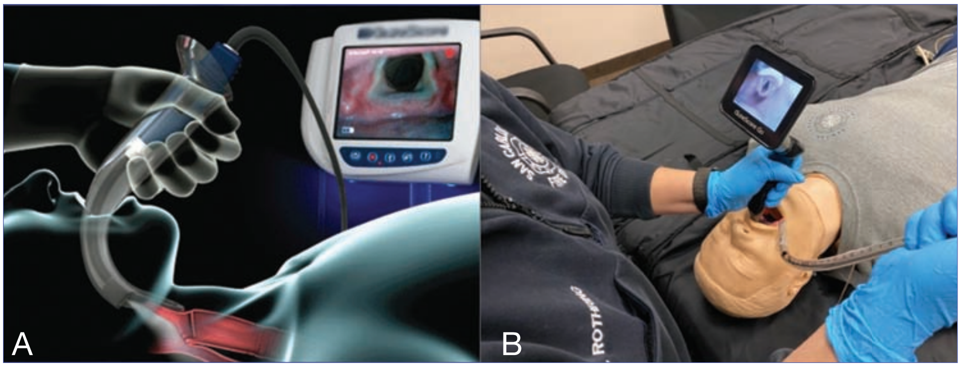

FIGURE 7.19 GlideScope VAL. (A) Separate monitor connected via a cable should be in the operator's line of vision and (B) all-in-one portable device. In either case, always hold the VAL with the left hand.

VAL, video-assisted laryngoscope.

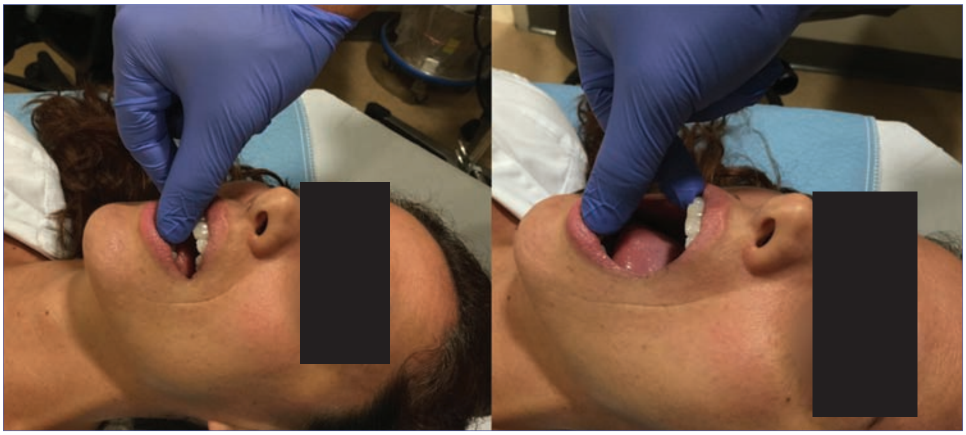
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FIGURE 7.20 Scissor technique used in opening the mouth.

VIDEO 7.1 Video-assisted laryngoscopy. Note that nasal cannula/apneic oxygenation is not shown and should be done in all cases of endotracheal tube intubation. Also, for endotracheal tube confirmation, rapid trachea ultrasound exam should be done before ventilations/auscultation.

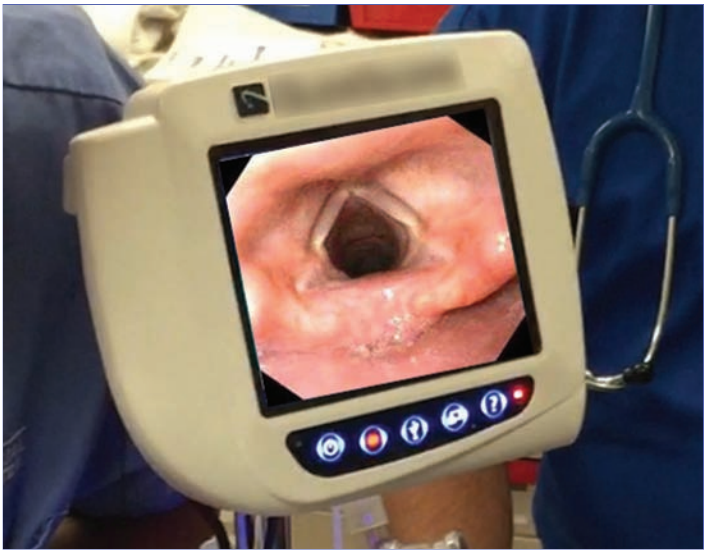


FIGURE 7.21 Video monitor displaying the glottis using video-assisted laryngoscopy with the blade positioned within the valleculum.

- Introduce the blade of the VAL into the center of the mouth **(VIDEO 7.1)**.
- Ensure that you are looking at the patient and not the video monitor until the blade is within the mouth, over the center of the tongue.
  - Do not sweep the tongue to the side as in DL.
- While looking at the video monitor, follow the tongue into the vallecula, deep and anterior to the visualized epiglottis (**FIGURE 7.21**).
- Rather than lifting, use more of a wrist abduction ("cocking of the wrist") movement and the glottis will come into view.
- Note that in DL one lifts in a 45-degree angle in an attempt to align the three airway axes.
- If there is difficulty visualizing the glottis, move blade slightly out of the mouth as sometimes overzealous placement puts the blade tip in the esophagus.
- In this case, one would see the epiglottis "pop" into sight as the blade is withdrawn.
- Keep your focus on the video monitor while having an assistant place a finger in the patient's mouth, pulling the bucca laterally, allowing more room for the VAL blade to occupy the mouth to make room for the ETT.
- Grasp and hold the ETT with stylet in place in your right hand and, while looking at the mouth, place into the right side of the mouth with the curved side facing up.
- Upon entry of the ETT into the mouth, focus again on the video monitor.
- Note that in DL, the most challenging part of ETTI is glottis visualization, as passing the ETT through the vocal cords is relatively easy because it is a more direct straight line; this is because the 45-degree upward angle of force applied by the laryngoscopist is increasing alignment of the three airway axes.
- In contrast, in VAL the most challenging part of ETTI is the actual placement of the ETT through the vocal cords, negotiating the 60-degree angle of curvature of the blade in terms of visualization.
  - In other words, glottis visualization is relatively easy whereas passing the ETT through the glottis may be slightly more challenging.
  - The ETT should be placed 4 to 5 cm above the carina.
    - Though recently challenged, classic teaching was to place the ETT to the lips in adults at:
      - 21 cm in adult females
      - 23 cm in adult males
      - Pediatric tube length is age/2 + 12
      - The strongest determinant of ETT depth is height and can be estimated with the following equation: (Height in centimeters/7) – 2.5
- Have an assistant remove the stylet, attach BVM or mechanical ventilator with capnography device, and inflate the cuff.
  - The cuff is inflated via the pilot balloon port with 5 to 10 mL of air to the minimum pressure required to prevent an air leak in order to isolate the trachea from the esophagus and prevent aspiration.

- Confirm tube placement (ideally with capnography—see next section "Confirming Proper ETT Placement."
- Do not release the ETT until adequately secured with a commercial endotracheal tube holder (preferably) or tape.

POSTPROCEDURE CONSIDERATIONS

Confirming Proper ETT Placement

Though it seems intuitive to know whether the ETT is in the trachea or the esophagus, evidence states up to 6% are placed in erroneous positions in pooled emergent studies. More importantly, the sequelae of a misplaced ETT can be devastating and significantly increase the morbidity and mortality by means of hypoxia, hypoventilation, gastric distension, and subsequent regurgitation/aspiration. There is no gold standard for determination of appropriate tracheal placement, and therefore multiple modalities are used in combination.

Classically taught methods of ETT tracheal confirmation:

- Direct visualization of the ETT entering the vocal cords—although reassuring, the tube can become dislodged or the operator fooled
- Auscultation of chest and epigastrium
  - Poor sensitivity
  - However, if auscultating, listen over the epigastrium first; if borborygmi is heard, immediately remove the ETT entirely
  - If no sounds over the epigastrium, listen to the left lung at the mid axillary line prior to the right lung
  - If breath sounds are heard, an endobronchial intubation is unlikely as most occur to the right mainstem due to its more vertical takeoff from the trachea
  - If no breath sounds on the left, but there are breath sounds on the right, pull back 2 cm and reassess, as it is likely the tube is too deep
- Fogging of the ETT and chest wall movement
  - Not specific
  - Classic canine study by Kelly et al. (1998) showed that in cases of esophageal intubations, fogging of the tube occurs in 50% of the cases
- CXR (**FIGURE 7.22**)
  - Although CXR can depict distance of ETT tip to carina as well as possible complications, such as pneumothorax and aspiration (delayed radiographic finding), it cannot determine whether ETT is in the trachea or esophagus.
  - Confirmation should occur immediately after placement, whereas obtaining a CXR may take minutes, placing patients at risk for prolonged esophageal ventilation.

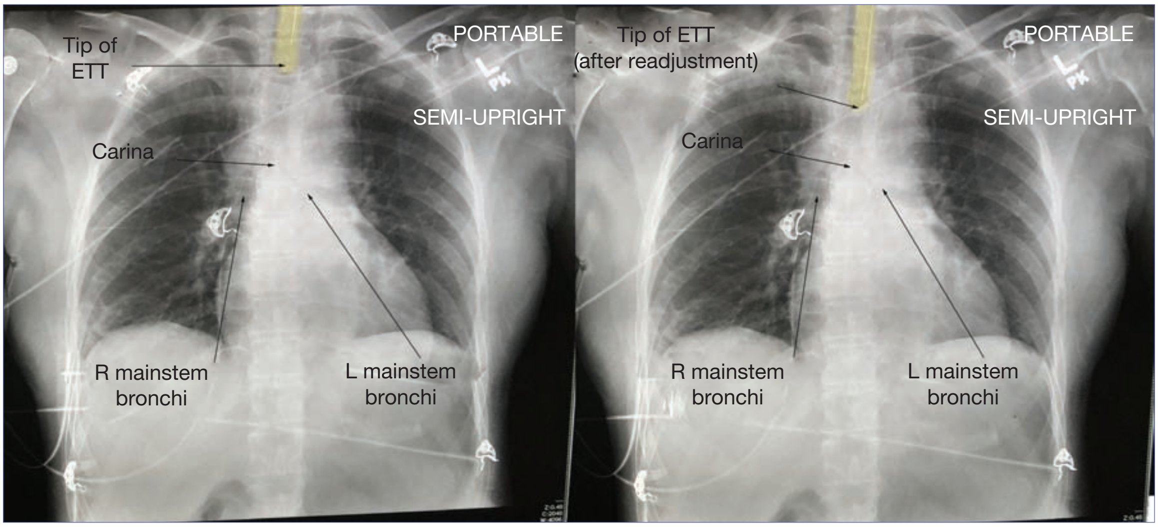


FIGURE 7.22 CXR with endotracheal tube in proper position above the carina in the picture on the right as opposed to the left image in which it is too high. Note that this modality does not rule in/out an esophageal intubation.
CXR, chest x-ray; ETT, endotracheal tube.

- Quantitative capnography
  - The American Heart Association (AHA), Advanced Cardiac Life Support (ACLS), and the American College of Emergency Physicians (ACEP) recommend use of capnography for confirmation of ETT placement.
  - Continuous waveform capnography (quantitative) is preferred over qualitative colorimetric capnography, with some studies demonstrating sensitivity and specificity of 100% in patients with spontaneous circulation.
  - Sensitivies decrease in patients with cardiac arrest; supplemental confirmatory modalities, such as ultrasound, can be used.
  - False positives may occur with supraglottic placement.
- Qualitative capnography
  - In patients with spontaneous circulation, appropriate color change may not be achieved until the sixth ventilation; if intubation is esophageal, recognition will be delayed, and patient may be at risk for aspiration.
- Bedside transtracheal ultrasound
  - As stated previously, ultrasonography is ubiquitous in acute-care settings and is usually immediately available.
  - Benefits of POCUS for placement of ETT include:
    - Identification of appropriate placement without need to deliver a breath, therefore reducing risk of aspiration
    - Ability to confirm placement without pausing chest compressions in patients with cardiac arrest
  - A 2018 meta-analysis (17 studies, 1,595 patients) by Gottlieb et al. determined that transtracheal ultrasound was 98.7% sensitive and 97.1% specific for verification of ETT location and carries a positive likelihood ratio (+LR) of 34.4 and a negative likelihood ratio (–LR) of 0.01 (**TABLE 7.5**).
    - A subgroup analysis did not determine any difference between provider specialty or experience.
    - The mean time to confirmation was found to be 13 seconds.

TABLE 7.5 Transtracheal Ultrasound for Verification of Location

Sensitivity	98.7% (95% CI, 97.8%–99.2%)
Specificity	97.1% (95% CI, 92.4%–99.0%)
+LR	34.4 (95% CI, 12.7–93.1)
–LR	0.01 (95% CI, 0.01–0.02)
Operating time	13 seconds

LR, likelihood ratio.

Source: Adapted from Gottlieb, M., Holladay, D., & Peksa, G. D. (2018). Ultrasonography for the confirmation of endotracheal tube intubation: A systematic review and meta-analysis. *Annals of Emergency Medicine, 72* (6), 627–636. https://doi.org/10.1016/j.annemergmed.2018.06.024

- Pertinent sonographic principles of transtracheal ultrasound:
  - Air and soft tissue have significantly different acoustic impedances.
  - Ultrasound waves are reflected off of surfaces with high density (anterior wall of trachea), resulting in hyperechoic images.
  - Ultrasound waves do not travel well through air-filled structures (tracheal lumen), resulting in artifact.
    - The posterior wall of the trachea is therefore not visualized.
  - On ultrasound, the trachea is depicted as an air–mucosal (A–M) interface:
    - A hyperechoic curvilinear structure with reverberation artifact, comet-tail artifact, and "air shadowing" posteriorly
  - The empty trachea appears sonographically the same as the trachea with the ETT in its lumen (**FIGURE 7.23**).

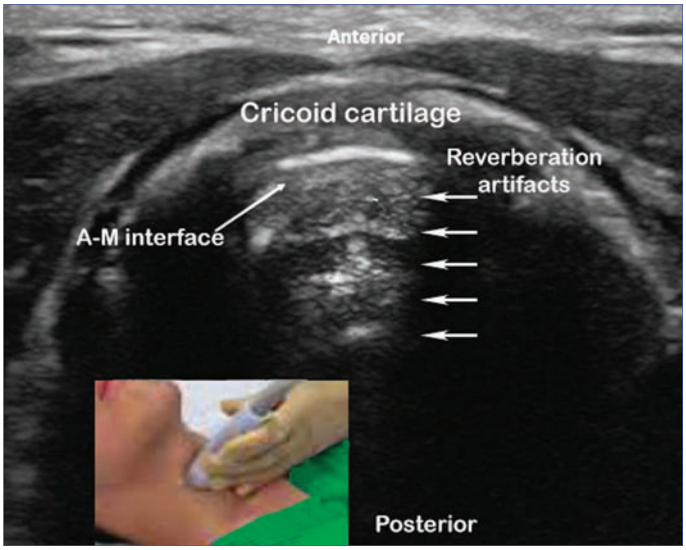


FIGURE 7.23 Reverberation artifact.

- The esophagus, conversely, is normally collapsed, does not possess an A–M interface, and therefore appears indistinguishable from the surrounding soft tissue of the neck.
    - An esophageal intubation will result in an esophagus with an A–M interface; therefore, a hyperechoic structure with artifact posteriorly will be seen.
        - In fact, it will appear as a second trachea, hence the term *double-lumen sign*.
- How to perform transtracheal ultrasound (**FIGURE 7.24**):
    - Place linear or curvilinear probe at suprasternal notch.
        - Identify number of A–M interfaces (**FIGURE 7.25**):
            - A single A–M interface indicates tracheal intubation (single-lumen sign).
            - A twisting motion of the ETT may add sensitivity **(VIDEO 7.2).**
            - Two A–M interfaces (double-lumen sign) indicates esophageal intubation.
        - Moving the probe laterally may help identify the second lumen as esophageal/tracheal anatomic relation can be variable, and in some cases the esophagus may be directly posterior to the trachea:
            - 80% posterior left
            - 16% directly posterior
            - 4% posterior right

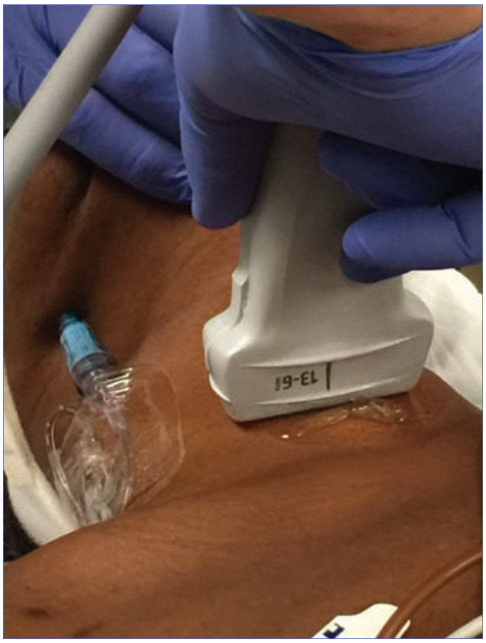


FIGURE 7.24 Trachea rapid ultrasound exam (TRUE).

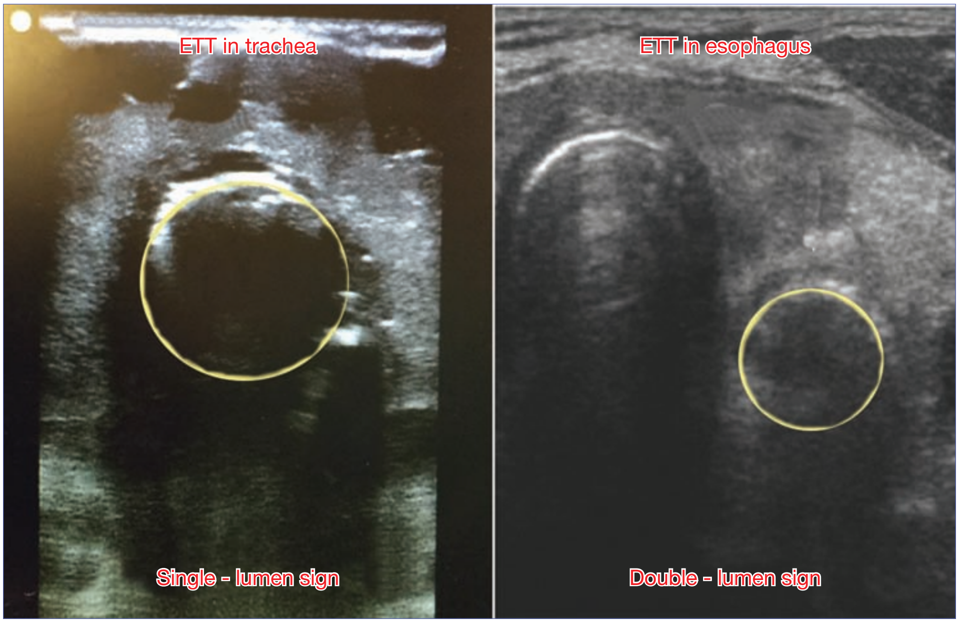
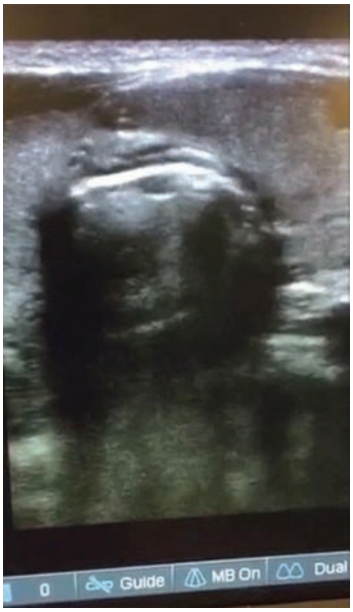


FIGURE 7.25 Ultrasound appearance of anterior neck upon trachea intubation. Note the double-lumen sign in the esophageal intubation.



VIDEO 7.2 Ultrasound of endotracheal tube in trachea upon twisting the tube.

Postintubation Care

- Mechanical ventilation parameters should be established and it is beneficial to discuss these with the respiratory therapy team.
- Shortly after RSI medication administration, the patient is still paralyzed and will therefore require assist-control/volume-control (AC/VC) ventilation.
  - Parameters include:
    - TV
    - RR
    - FiO_2
    - PEEP
  - Details of setting these parameters are beyond the scope of this chapter.
- Once endotracheal placement of the ETT is confirmed, gastric decompression should be accomplished by placing an orogastric tube (OGT) to suction.
- Elevation of the head of the bed should remain at 30–45 degrees if not already adjusted.
- Postintubation sedation/analgesia is critical and must be achieved with potent medications such as fentanyl, propofol, or dexmedetomidine.

EDUCATIONAL POINTS

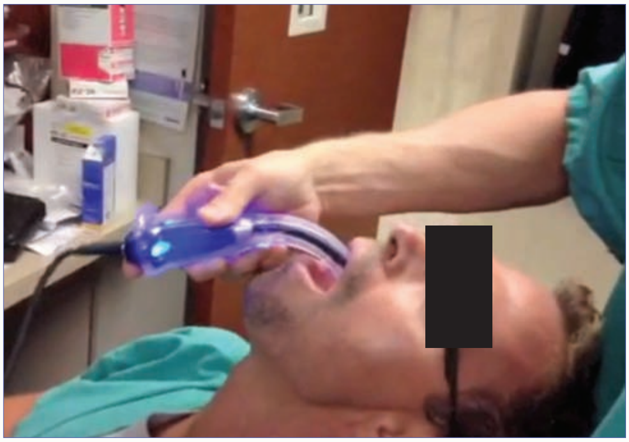
- Understand upper airway anatomy; appreciate the differences between adult and pediatric patients.
- Ear-to-sternal notch positioning can be used to optimize alignment of the oral, pharyngeal, and laryngeal axes.
- Head/torso-up elevation throughout all phases of preoxygentation, RSI, and VAL may have a beneficial effect in regard to alveolar recruitment and offsetting hypoxia.
- Indications for ETTI include altered mental status, airway compromise, inability to oxygenate/ventilate, and the postresuscitation cardiac arrest patient.
- Preoxygenation: At minimum, provide 3 minutes of NRB at 30 L/min; if unable to sufficiently preoxygenate, patient is likely displaying shunt pathology and/or in a state of shock.
  - Shunt: Patient will benefit from PPV in the form of BVM or BiPAP.
  - Shock: Resuscitate before you intubate; intubation can lead to further hypoxia, hypercapnia, and hypotension; optimize these variables prior to induction with RSI and ETTI.
- BVM: Ensure a PEEP valve is connected; two-handed method is better than one-handed C–E grip; use the minimum volume necessary to generate visible chest rise to limit aspiration risk as the LES opens at a pressure of 25; use a manometer on the BVM and aim to keep pressures less than 20.
- BiPAP: Consider BiPAP for all patients in respiratory distress who are candidates; this may alleviate the need for ETTI, or be used to further preoxgenate, especially in patients with shunt pathology.
- Consider RSI in agitated or combative patients who are not cooperating with preintubation optimization; remember that preoxygenation is a procedure in itself and one may need to use ketamine in order to accomplish this required phase of RSI.
- Consider use of SGA in crash airways and prehospital airways, or if clinician performing airway is inexperienced with ETTI, or after multiple attempts at ETTI; SGAs are not protected airways and patients are at risk of aspiration.
- If patient does not need a crash airway, prepare for RSI; know contraindications and adverse effects of RSI medications.
- The literature clearly has shown that VAL is easier to master and maintain than DL and is recommended for all, especially novice intubators.
- Quantitative capnography is the gold standard for confirmation of tracheal placement of ETT; however, it is not 100% accurate; use multiple modalities to confirm ETT placement.
- Post intubation care includes appropriate ventilator settings, sedation, orogastric tube (OGT) placement, and soft restraints when necessary.
- The best way to safely recruit lungs during bag-mask ventilation is to slowly insufflate *low* TVs (thereby achieving a low peak pressure) while using generous PEEP.
- Ketamine should be the induction agent of choice in shock and asthmatic patients.
- Risk factors for cardiac arrest postintubation include:
  - Hypotention
    - Correct this first.
  - Hypoxia
    - Correct this first.
  - Metabolic acidosis

COMPLICATIONS

- Immediate complications:
  - *Unrecognized* esophageal intubation, leading to gastric distention/aspiration and perhaps gastric rupture
  - Endobronchial intubation
  - Iatrogenic hypoxia/hypercapnia
  - Traumatic injury to lips, teeth, pharyngeal soft tissue, vocal cords
  - Exacerbation of cervical spine injuries
  - Exacerbation of unrecognized pneumothorax, causing tension pneumothorax
  - Hypotension from increased intrathoracic pressure and decreased cardiac preload; possible cardiac arrest if patient is under-resuscitated
- Late complications:
  - Laryngeal injury from direct pressure of the ETT on the larynx
  - Laryngeal edema
  - Laryngeal stenosis
- Need for tracheostomy
- Infection/inflammation
- Aspiration pneumonitis, pneumonia
- Ventilator-associated pneumonia (VAP)—Hospital-acquired pneumonia that develops at least 48 hours after ETTI. Early extubation counteracts this.

PEARLS

- In unconscious patients:
  - Assume partial/full airway obstruction, perform jaw thrust.
  - Evaluate for easily reversible causes of unconsciousness such as opioid toxicity, hypoglycemia, and/or hypoxia.
- Impending respiratory failure is a clinical diagnosis—assess breath sounds, work of breathing, vital signs; do not wait for imaging or lab values to determine whether a patient needs to be intubated.
- Resuscitate before you intubate.
- Ensure appropriate preoxygenation; BVM can be used to preoxygenate when the risks of hypoxia outweigh the risk of aspiration.
- Preparation prior to intubation is key: Consider the use of an equipment checklist as used by professional pilots.
- Once the ETT is secure, start considering what needs to be achieved in order to facilitate early extubation.
- Be familiar with all airway equipment available in your practice setting.
- Robust literature consistently supports the use of VAL over DL in regard to achieving a higher success rate for visualization of the glottis and duration of training needed to maintain proficiency (**VIDEO 7.3**).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VIDEO 7.3 Simplicity of the video-assisted laryngoscopy.

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CHAPTER

8

Cricothyrotomy

Danielle Betz and David A. Wald

BACKGROUND

In the practice of emergency medicine, there are few more feared clinical scenarios than that of the difficult airway and the dreaded scenario of a "cannot-intubate, cannot-ventilate" situation. Intubation, frequently rapid sequence intubation (RSI), is performed in the ED for patients suffering from some combination of hypoxic or hypercarbic respiratory failure resulting from myriad causes. Luckily, in the overwhelming majority of these cases, the patient's airway can be properly secured. Few patient presentations create more anxiety, regardless of the number of years in practice, than the potential surgical airway.

The Practice Guidelines for Management of the Difficult Airway (American Society of Anesthesiologists Task Force on Difficult Airway Management, 2003) dictate ***a difficult airway is encountered when a practitioner trained in airway management experiences difficulty with bag-valve mask (BVM) ventilation, tracheal intubation, or both***. For these scenarios, there may be a host of patient and clinician factors that play a role in making the airway difficult to manage. Note that the inability to intubate using an endotracheal tube (ETT) does not dictate a failed airway: it simply means an ETT cannot be passed. As long as the patient can be ventilated with detection of adequate end-tidal CO_2 ($ETCO_2$) via any means (BVM, supraglottic airway, etc.), the airway is not failed.

To reiterate, the inability to ventilate via any means dictates a failed airway. Though difficult/failed airway algorithms from the Difficult Airway Society (DAS) and the American Society of Anesthesiologists (ASA) exist, a failed airway leads to the need for a cricothyrotomy. Only the Shock Trauma Center (STC) failed airway algorithm has been studied. In this algorithm, after three unsuccessful attempts at endotracheal intubation, an escalation to a supraglottic airway should occur; if ventilation is compromised with this modality or if O_2 saturation decreases, the clinician should escalate immediately to a cricothyrotomy.

There is supporting literature for this and similar algorithms. When more than two attempts at endotracheal intubation are unsuccessful, complications are much more likely to occur (**FIGURE 8.1**).

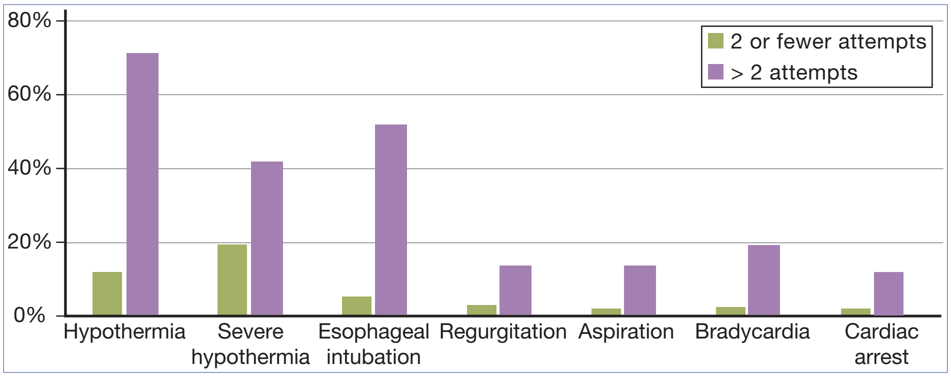


FIGURE 8.1 Morbidity and mortality exponentially increase after two attempts of endotracheal tube placement in the critical patient.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

The clinical scenario of the failed airway (***an inability to ventilate and oxygenate)*** requires critical thinking and definitive action to prevent further complications. Anticipation and preprocedural rehearsal are paramount; if one is contemplating securing a potentially difficult airway, one should simultaneously prepare for a potential unable-to-ventilate scenario (double setup).

Although the true incidence of the failed airway historically has been cited at 1% of cases, a 2002 study of the National Emergency Airway Registry database found that only 0.56% (43 of 7,712) of intubations required cricothyrotomy (aka cricothyroidotomy). In another large series of more than 17,000 ED intubations, 99% of patients were able to be intubated successfully in three or fewer attempts. In approximately one-third of the remaining cases, a rescue cricothyrotomy was performed. The incidence of emergent cricothyrotomy has decreased over the years because of many new techniques, including but not limited to, the following:

- Video-assisted intubation
- Supraglottic airways
- Fiber-optic devices
- Increased prevalence of trained emergency clinicians
- New preoxygenation, positioning, and apneic oxygenation techniques
  - All prolong time of safe apnea
- Better ventilation strategies
  - Low volume/pressure
  - Positive end-expiratory pressure (PEEP) valves
  - Nasal cannula with BVM ventilation

Anatomy

The anterior anatomy of the neck is composed of a number of structures: skin, muscle, cartilage, nerves, trachea, blood vessels, and so on. Although a detailed description is beyond the scope of this chapter, a basic knowledge of the upper airway is critical to gaining skill in this most lifesaving of procedures. Furthermore, a concise review of these structures has previously been published. With the patient in the supine position, midline anterior landmarks of the neck from superior to inferior include the floor of the mouth, hyoid bone, thyrohyoid membrane, thyroid cartilage, cricothyroid membrane (CTM), cricoid cartilage, and the sternal notch (**FIGURE 8.2**). Note the vascular anatomy as well, specifically, the superior thyroid vessels (lateral) as well as the cricothyroid vessels at the superior margin of the relatively avascular CTM. The most prominent anterior midline landmark that should be identified is the thyroid cartilage. Just inferior to the thyroid cartilage is the dense fibroelastic CTM, which separates the thyroid and cricoid cartilage. A cadaveric study has shown that the average width/height is 12 mm/8.4 mm. ***Proper identification of these anatomic landmarks is paramount to performing a successful cricothyrotomy.***

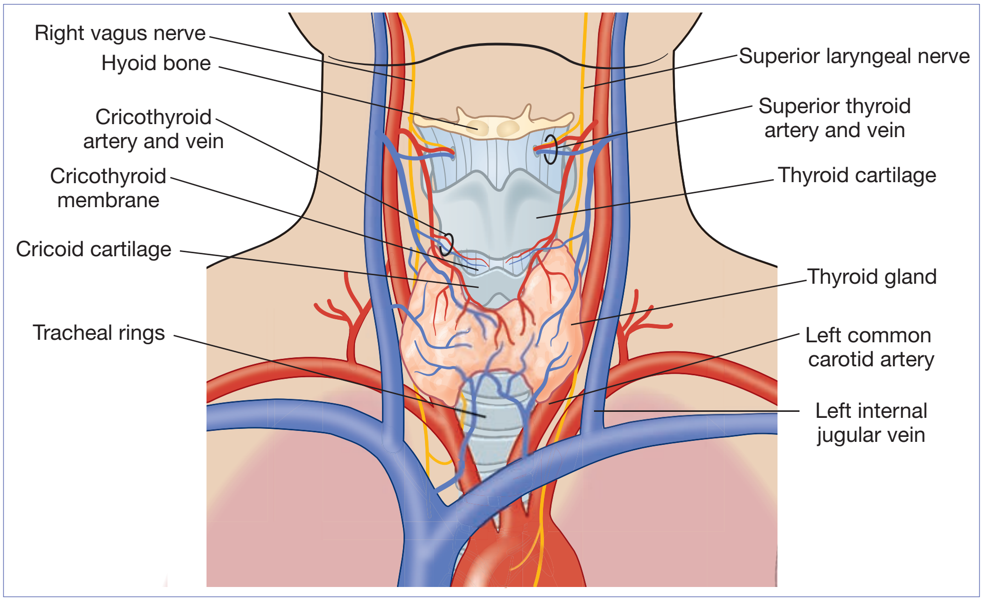


FIGURE 8.2 Anterior neck anatomy.

Note the CTM may not be easily identified in patients with the following characteristics:

- Obesity
- Radiation therapy
- Prior surgery
- Trauma
- Congenital disorders

For this reason, the authors recommend the use of ultrasound as it has been reported to identify the CTM more accurately than external palpation in patients with normal neck anatomy and abnormal neck anatomy (**FIGURE 8.3**). In a study on human cadavers with poorly defined neck landmarks, Siddiqui Arzola, Friedman, Guerina, and You-Ten (2015) showed a significantly greater success rate of cricothyrotomy and a three-fold reduction in complications with ultrasound identification compared to external palpation of the CTM. Likewise, a randomized trial of 223 adult patients with neck pathologies, such as previous neck surgery, irradiation, and/or neck mass, who were scheduled for a neck CT scan were randomly allocated to either an ultrasound group or palpation group in terms of accurate identification of the CTM. The ultrasound group had a 10-fold greater chance of correct identification than the palpation group (81% vs. 8%). Finally, recent research has indicated that accuracy of the identification of the CTM can be as low as 30%, even in the hands of skilled clinicians.

Note that pediatric anatomy differs greatly from adults:

- Larynx is superior and anterior
- Funnel shaped
- Much smaller CTM
  - Thyroid and cricoid cartilages actually touch each other laterally

PATIENT PRESENTATION

Any patient with a failed airway may require a cricothyrotomy if oxygenation and ventilation cannot be performed by other means, including the use of an airway adjunct or a rescue device.

TREATMENT

There are three described methods of establishing an airway once intubation has failed. For ethical reasons, there are no prospective studies comparing emergency cricothyrotomy techniques on living patients. A meta-analysis of prehospital airway access techniques in patients found published studies of low quality, but concluded that the surgical cricothyrotomy was associated with success rates of 90%, whereas nonsurgical cricothyrotomy had lower success rates of 65%. A randomized cadaveric study resulted in similar outcomes with a 95% success rate in the surgical technique versus 50% with the Seldinger technique. However, a systematic review presented a handful of studies comparing Seldinger to

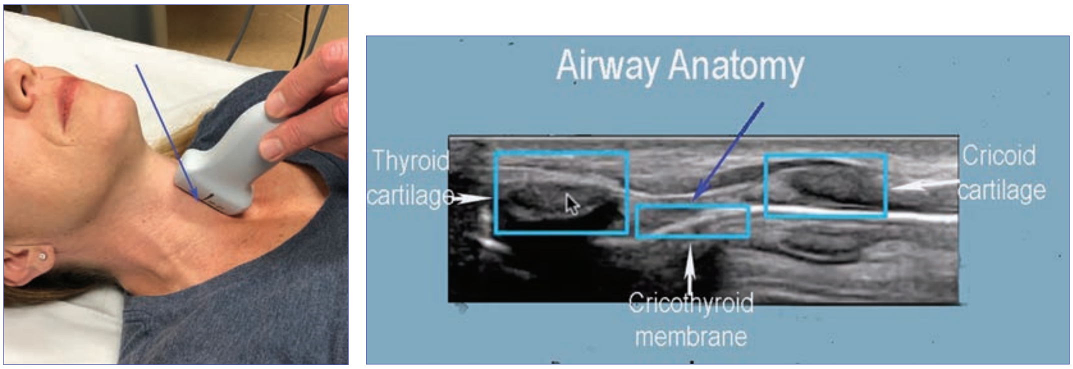


FIGURE 8.3 Ultrasound identification of CTM anatomic structures. The ultrasound waves emitted by the ultrasound transducer pass quite easily through cartilage. For this reason, cartilage appears hypoechoic on the ultrasound screen, as very few sound waves are echoing back to the transducer. Air is a poor medium for the passage of ultrasound waves and the junction between the soft tissues of the airway and the air within the trachea (air–mucosal interface) generates a hyperechoic signal. Using a skin marker, one can mark the CTM accurately using this technique in anticipation of a potential difficult airway.

CTM, cricothyroid membrane.

open cricothyrotomy in simulation labs; both with equal success rates, although surgery was faster. Another observational study has shown that the average time needed to perform the open technique of 24 sequential cases was 83 seconds.

1. **Open surgical cricothyrotomy (FIGURE 8.4)**
   - Procedure allows for insertion of a conventional ETT (6.0) or a tracheostomy tube (Shiley).
   - Requires only basic equipment, which should be readily available in the ED.
   - Equipment needs can be as minimal as a scalpel and an ETT.
   - This is a true surgical technique that requires knowledge and skill.
   - Inadvertently incising anterior neck vessels (see **FIGURE 8.2**) can induce significant bleeding that obscures the field.
2. **Large-caliber percutaneous Seldinger approach (FIGURE 8.5)**
   - Requires specialized, prepackaged kits

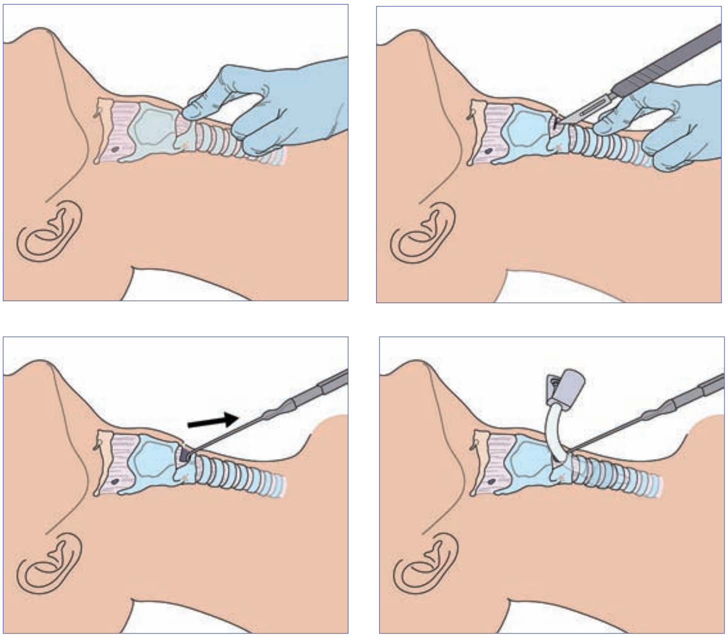


FIGURE 8.4 Open surgical cricothyrotomy.

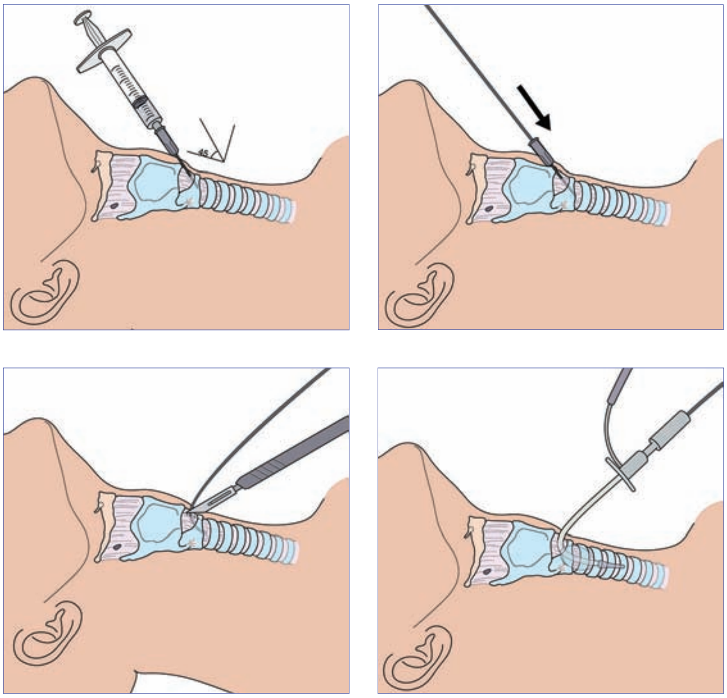


FIGURE 8.5 Large-caliber percutaneous Seldinger approach.

3. **Small-caliber percutaneous approach/needle cricothyrotomy/transtracheal jet ventilation (TTJV) technique (FIGURE 8.6)**
    - A needle cricothyrotomy is performed with a large-bore intravenous cannula.
    - An ETT cap is used between the angiocatheter and the BVM.
    - As an alternative, high-pressure oxygen via tubing is used for jet insufflation through the cannula, although this will be unfamiliar to most clinicians.

CONTRAINDICATIONS AND RELATIVE CONTRAINDCATONS

- **Open surgical cricothyrotomy**
    - Similar to contraindications for open surgical cricothyrotomy
    - There are no absolute contraindications for a surgical cricothyrotomy except for the ability to secure an airway by less invasive means; the exception to this is the patient who has suffered massive airway trauma with tracheal transection or cricoid or laryngeal fracture, as the anatomy will either be inaccessible or inadequate for access to the trachea.
    - Other situations involving a failed airway should be managed with a surgical cricothyrotomy with several relative contraindications:
        - Massive swelling, hematoma, or obesity with the loss of anatomic landmarks
        - Pediatrics (<5 years)

Because of the differences in the pediatric anatomy (no consensus but in general <5 years old), jet ventilation is recommended.

- **Small caliber percutaneous approach/needle cricothyrotomy/transtracheal jet ventilation (TTJV) technique**
    - There is no cuff or seal to prevent aspiration.
    - Often this approach is not adequate for ventilation longer than 30 minutes so it is therefore, at best, a temporizing measure for improving oxygenation/ventilation.
    - There is a high incidence of barotrauma via "breath stacking."
- Contraindications—None: Avoid with complete upper airway obstruction as this can cause increased intrathoracic pressure leading to barotrauma, though this technique may be used in partial airway obstruction.

SPECIAL CONSIDERATIONS

Needle cricothyrotomy is similar to the Seldinger-technique variation of a cricothyrotomy and is generally reserved for those pediatric patients less than 5 years old (some literature states 8 years old) as a temporizing bridging procedure in order to get the patient to the operating room (OR) for a definitive tracheostomy.

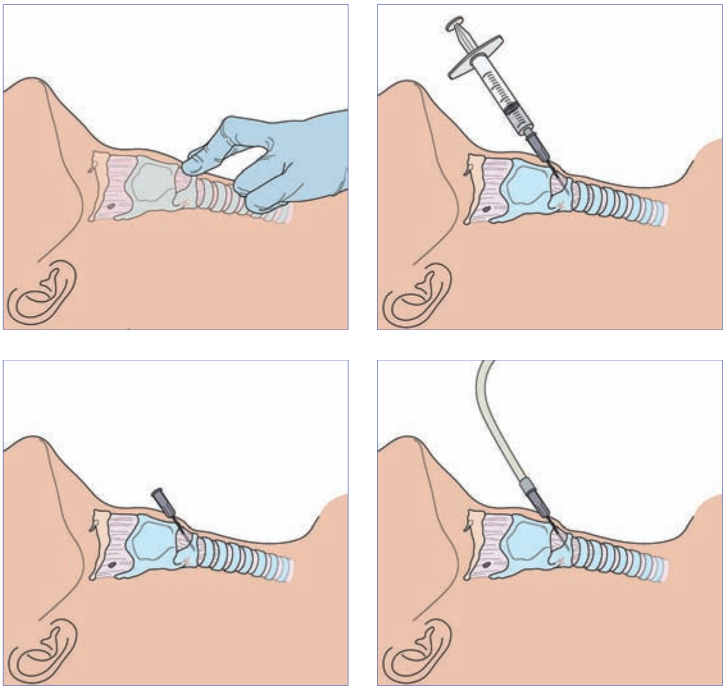


FIGURE 8.6 Small-caliber percutaneous approach/needle cricothyrotomy/transtracheal jet ventilation technique.

In the pediatric patient younger than 5 years old, the CTM is very narrow, which can result in failed placement of a surgical airway and is also associated with an increased risk of permanent laryngeal injury (arytenoids/vocal cords sit directly behind the inferior larynx). In this age group, a needle cricothyrotomy is historically the preferred method to access the failed airway, though the literature is somewhat conflicted with regard to the age at which an open or Seldinger cricothyrotomy can be safely performed (ranges from 5 to 8 years). With ultrasound and prepackaged needle cricothyrotomy kits, this dogmatic approach remains controversial despite acknowledging that when a child is under 5 years of age, the CTM is narrow and small.

Duggan et al. (2016), in a robust meta-analysis, looked at 44 studies totaling 428 needle cricothyrotomies and questioned guidelines supporting cricothyrotomy use secondary to the following findings:

- Device failure occurred in 42% of emergency cases.
- Barotrauma occurred in 32%.
- TTJV induced significant subcutaneous emphysema, hampering subsequent attempts at surgical airway or tracheal intubation.
- Recommended equipment (some "homemade") is varied; there is a paucity of evidence on equipment use and clinicians may be unfamiliar with it.

PROCEDURE PREPARATION

In the ED, a cricothyrotomy is an unplanned lifesaving procedure attempted only when a failed airway is encountered. Standard airway equipment should always be available when performing an intubation. Additional rescue devices, airway adjuncts, and a cricothyrotomy kit should be available as some patients will have an unexpected difficult airway. At its most basic level, a cricothyrotomy can be performed with a No. 11 blade scalpel and 6.0-mm ETT or size 4 tracheostomy tube (Shiley™). Some institutions may have prepackaged or proprietary cricothyrotomy kits or trays, which may include additional equipment. Additional optional equipment may include a Trousseau dilator and a tracheal skin hook.

Given the high stakes of this lifesaving procedure, the infrequency with which it is performed, and the typically stressed and chaotic environment surrounding the need to perform a cricothyrotomy, mental preparation, visualization, and repetitive training are instrumental to success as they are to any high-stakes/seldom-performed procedures. One key aspect of training, specifically simulation training using either a task trainer or a high-fidelity simulator, is being prepared to "cut the neck." It is also important to be familiar with any prepackaged or percutaneous cricothyrotomy kits.

PROCEDURE

Regardless of which technique is used, the supine position with the neck hyperextended lends itself to the best identification of the CTM. Unless the patient has a known or suspected cervical spine injury, hyperextend the neck to more readily identify the landmarks. Preoxygenate the patient by any means possible. The following should be assembled in preparation regardless of technique selected:

- Skin cleanser
    - In a "crash airway" one may not have time to thoroughly apply this; at a minimum quickly apply chlorhexidine or betadine to the anterior neck.
- Sterile gown
- Sterile gloves
- Mask
- Face shield
- Sterile towels/drapes

Standard Open Cricothyrotomy

Equipment (**FIGURE 8.7**):

- 4 × 4 gauze pads
- No. 11 blade scalpel
- Needle/syringe with a small amount of saline in hub
- Tracheal hook
- Trousseau trachea dilator or curved hemostats

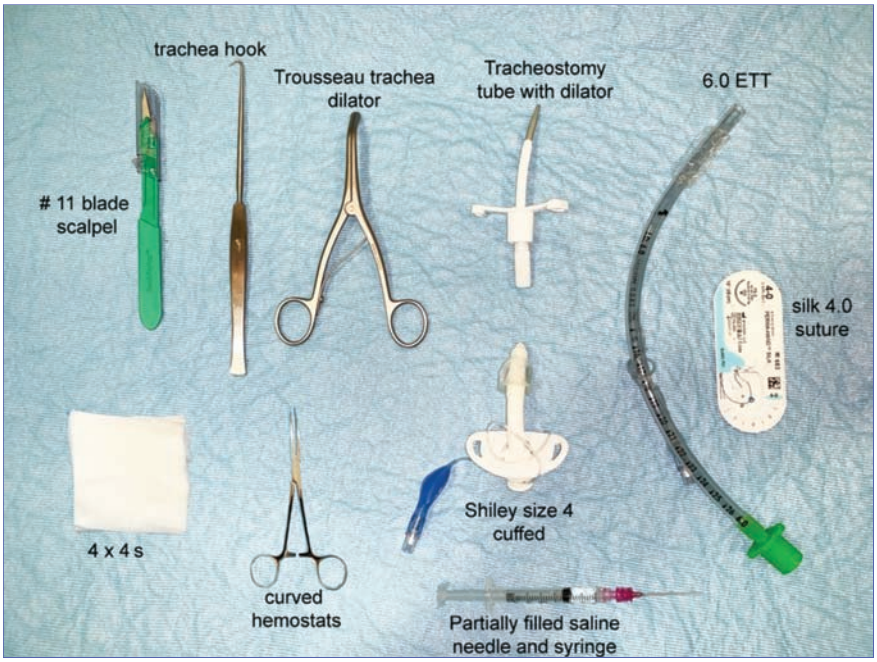
- Tracheostomy tube with dilator
  - 6-0 ETT
  - Shiley size 4 cuffed (has an inner/outer diameter of 5.0/9.4 mm)
- Silk 4-0 suture

Procedure:

1. Identify and palpate landmarks: If time permits, ultrasound can be considered to assist in landmark identification.
2. Using your thumb and third finger of the nondominant hand, stabilize the trachea with a firm grip; your index finger should palpate over the CTM (**FIGURE 8.8**).
3. Make a vertical midline 3- to 5-cm incision over the CTM (**FIGURE 8.9**).
   a. Resting the hand on the sternum adds stability.
   b. This incision should be firm, cutting through the subcutaneous tissue.

FIGURE 8.7 Open cricothyrotomy equipment. Note that a tracheostomy tube with a dilator (preferred), Shiley cricothyrotomy tube, or an ETT can be used.

ETT, endotracheal tube.


trachea hook
Trousseau trachea dilator
Tracheostomy tube with dilator
6.0 ETT
# 11 blade scalpel
silk 4.0 suture
4 x 4 s
curved hemostats
Shiley size 4 cuffed
Partially filled saline needle and syringe

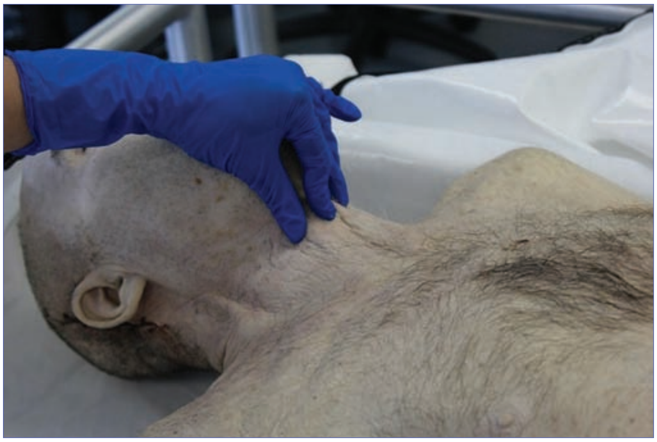


FIGURE 8.8 Palpation of the CTM while stabilizing the trachea.

CTM, cricothyroid membrane.

Source: Courtesy of Dr. Steven Popoff, Human Anatomy Lab, Lewis Katz School of Medicine, Temple University.

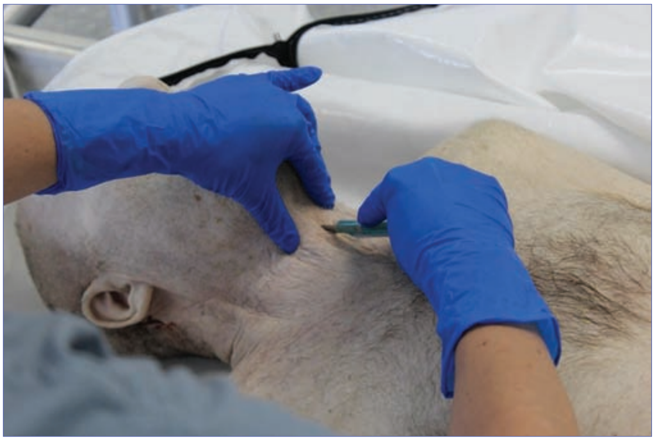


FIGURE 8.9 Making a vertical midline incision over the CTM.

CTM, cricothyroid membrane.

Source: Courtesy of Dr. Steven Popoff, Human Anatomy Lab, Lewis Katz School of Medicine, Temple University.

4. Identify the CTM via blunt subcutaneous dissection using your finger (**FIGURE 8.10**). Curved hemostats may facilitate this step.
5. Make a generous transverse stab incision through the lower half of the CTM in order to avoid the cricothyroid arteries **(see FIGURES 8.2** and **8.11**).
    a. Be sure to direct only the tip of your scalpel caudally to avoid the vocal cords, avoiding the posterior wall of the trachea.
    b. Insert a finger, bougie, or tracheal skin hook into the trachea to help guide the ETT through it.
        i. The tracheal hook can be used to stabilize the inferior aspect of the larynx especially in the patient with a thick neck or hypermobile larynx (**FIGURE 8.12**).
            1). Curved hemostats
        ii. Widen the CTM incision with a curved hemostat or Trousseau trachea dilator if available (**FIGURE 8.13**).
6. Place the ETT or tracheostomy tube directly into the trachea (**FIGURE 8.14**).
    a. Recent literature supports the use of a bougie to facilitate the passage of the ETT over other techniques (see **FIGURE 8.16**).
7. Inflate the balloon.

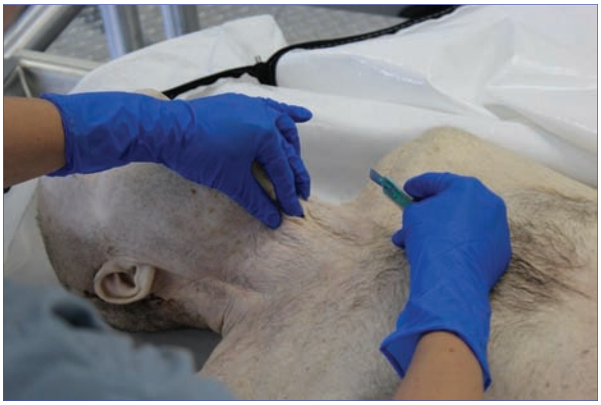


FIGURE 8.10 Identify the CTM via blunt dissection.

CTM, cricothyroid membrane.

Source: Courtesy of Dr. Steven Popoff, Human Anatomy Lab, Lewis Katz School of Medicine, Temple University.

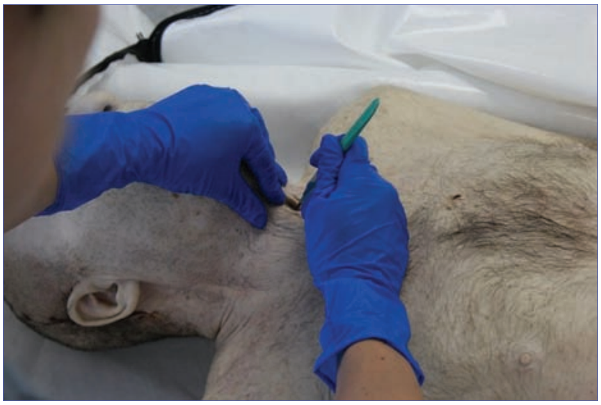
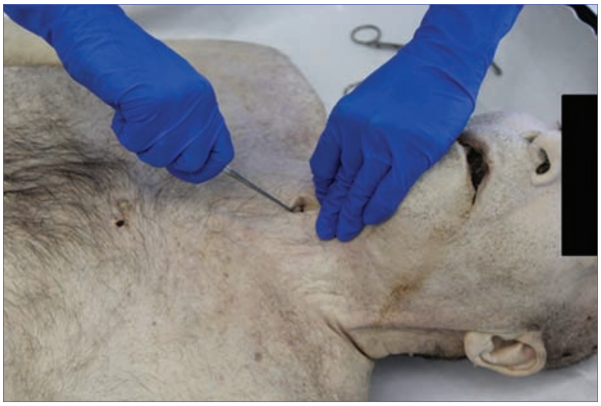


FIGURE 8.11 Making a short transverse stab incision through the CTM. Note the hand is resting on the sternum for added stability.

CTM, cricothyroid membrane.

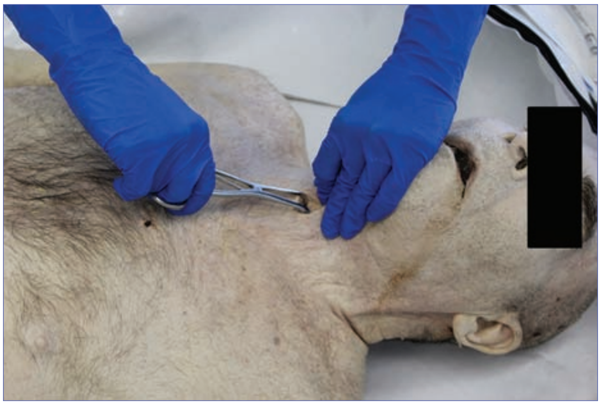
Source: Courtesy of Dr. Steven Popoff, Human Anatomy Lab, Lewis Katz School of Medicine, Temple University.



[redacted]

FIGURE 8.12 Stabilizing the inferior aspect of the trachea using tracheal hook.

Source: Courtesy of Dr. Steven Popoff, Human Anatomy Lab, Lewis Katz School of Medicine, Temple University.



[redacted]

FIGURE 8.13 Widening the incision with a Trousseau dilator (or curved hemostat).

Source: Courtesy of Dr. Steven Popoff, Human Anatomy Lab, Lewis Katz School of Medicine, Temple University.

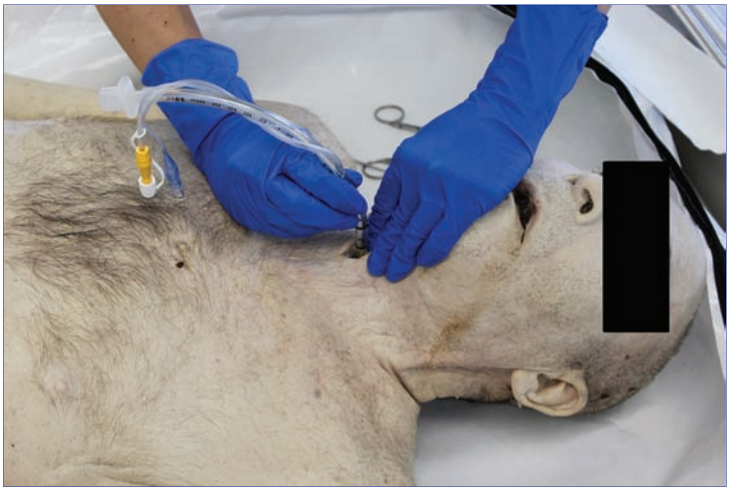

[redacted]

FIGURE 8.14 Insert the ETT in the trachea (or Shiley, shown in **Figure 8.15A**). Not shown here, bougie should be inserted first and the ETT should be inserted over the bougie in a Seldinger technique.

ETT, endotracheal tube.

Source: Courtesy of Dr. Steven Popoff, Human Anatomy Lab, Lewis Katz School of Medicine, Temple University.

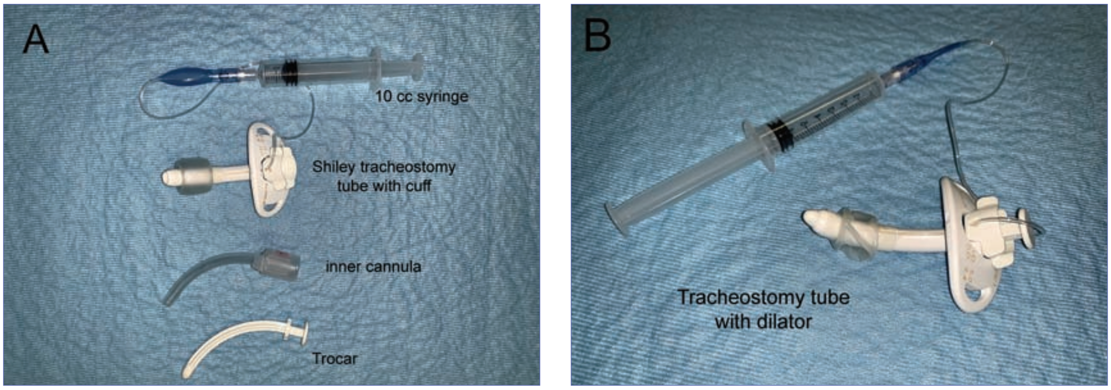

A
10 cc syringe
Shiley tracheostomy tube with cuff
inner cannula
Trocar
B
Tracheostomy tube with dilator

FIGURE 8.15 (A) Shiley tracheostomy tube may be used instead of an endotracheal tube. Not shown, recommend using a bougie first and a Shiley inserted over it using the Seldinger technique. (B) A tracheostomy tube with a dilator may be used as well.

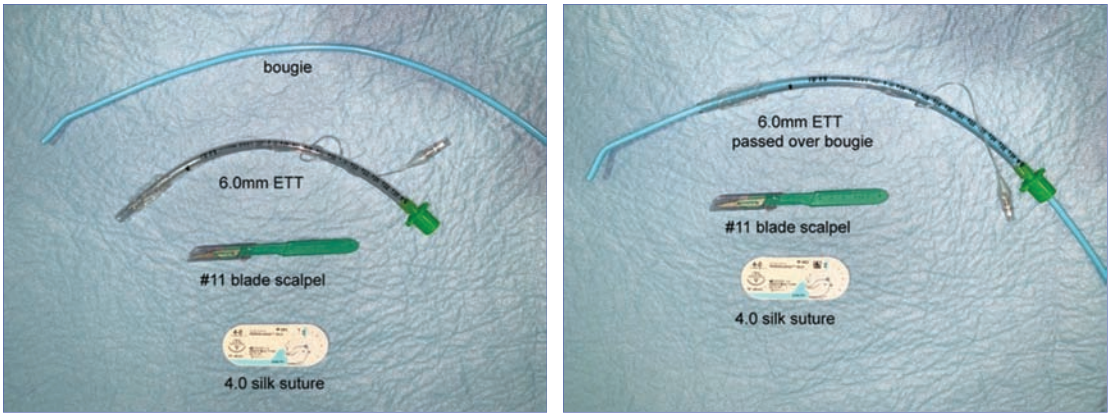

bougie
6.0mm ETT
#11 blade scalpel
4.0 silk suture
6.0mm ETT passed over bougie
#11 blade scalpel
4.0 silk suture

FIGURE 8.16 Equipment for open cricothyrotomy using a bougie. Recommend using a bougie whenever using an ETT or a Shiley device and taking advantage of the Seldinger technique.

ETT, endotracheal tube.

8. Confirm correct placement with end-tidal capnography and by auscultation of equal bilateral breath sounds.
9. Suture and secure the ETT or tracheostomy tube (**FIGURES 8.17** and **8.18**).

Variations of the standard open cricothyrotomy procedure have been published in the literature. All of these methods combine the initial tasks followed for the open technique: preparing the skin with antiseptic, identifying and palpating landmarks, and stabilizing the trachea with the nondominant hand. The bougie-assisted cricothyrotomy technique (BACT), scalpel–finger–tube method, and rapid four-step technique are briefly discussed. ***Based on recent literature, the BACT is recommended by the authors.***

BACT METHOD

1. Create a vertical incision from the base of the thyroid cartilage to above the sternal notch.
2. Create a transverse incision through the CTM and place your finger in the hole.
3. Replace your finger with a bougie, placing it through the hole into the trachea and inserting in a caudal direction; generally it advances 10 cm until resistance is met at the carina.
    a. With the curved tip of the bougie, one may "ride" the bougie up and down the trachea and appreciate the trachea rings.

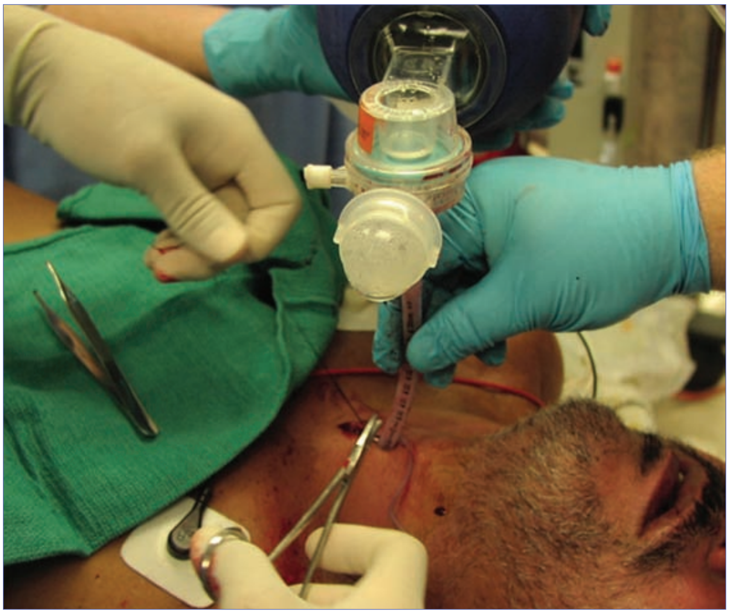


FIGURE 8.17 Suturing the ETT.
ETT, endotracheal tube.

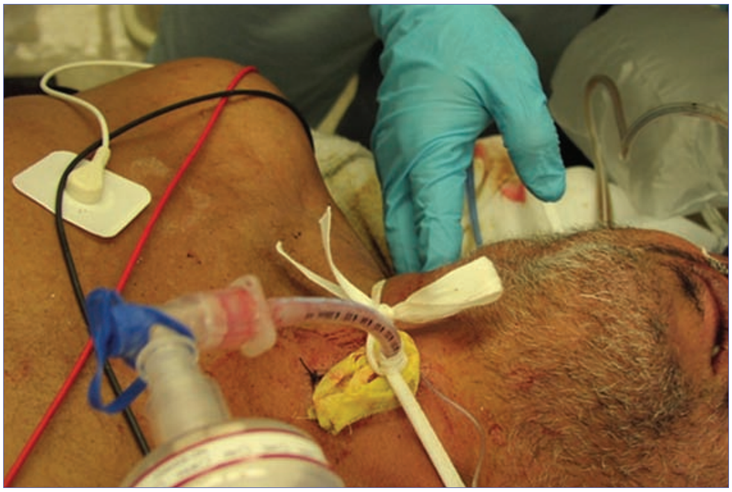


FIGURE 8.18 Securing the ETT.
ETT, endotracheal tube.

4. Pass an ETT over the bougie (**VIDEO 8.1**).

BACT is very similar to the traditional open method except it uses a bougie to stabilize the trachea instead of a tracheal hook, coupled with functioning as a Seldinger method.

- The finger placement of the bougie method gives you a continuous connection to the inside of the trachea.
- *You MUST use a tracheostomy tube or ETT that has an inner diameter of AT LEAST 5.5 mm or it will not pass over the bougie (***FIGURE 8.16***).*

SCALPEL–FINGER–TUBE

1. Incise horizontally all the way through the skin and CTM.
2. Extend incision laterally to allow for insertion of a gloved finger or the handle of the scalpel.
3. Insert a cuffed ETT between the finger (placed in the trachea already) and the trachea.

RAPID FOUR-STEP TECHNIQUE

1. Create a vertical incision from the base of the thyroid cartilage to above the sternal notch.
2. A horizontal stab incision is made through the membrane, creating a 2.5-cm horizontal incision.
3. Using the left hand, place the tracheal hook through the incision made into the trachea, turn the hook 90 degrees inferiorly, and apply caudal traction to the superior margin of the cricoid cartilage with the left hand resting on the patient's sternum.
4. Insert the ETT with the right hand. Remove the tracheal hook and inflate the cuff.

LARGE–CALIBER PERCUTANEOUS SELDINGER APPROACH

Equipment (**FIGURE 8.19**):

- 4 × 4s
- No. 11 blade scalpel
- Needle/syringe with a small amount of saline in hub
- Guidewire
- Tracheostomy tube with dilator
- Silk 4-0 suture

Procedure (**VIDEO 8.2**):

1. Identify and palpate landmarks.
    a. Considering the poor sensitivity of landmarks, ultrasound is best if time permits.
    b. In this rapid cricothyrotomy, the vertical incision might not be necessary if landmarks are easily palpable.
2. Using your nondominant hand, stabilize the trachea with a firm grip using your thumb and index finger.
3. With the dominant hand, attach the partially filled needle syringe and insert it through the CTM pointing caudally at a 45-degree angle and look for air bubbles as this will signify that the needle is in the trachea.
4. While holding the caudally positioned needle with the nondominant hand, place the guidewire through the needle with the dominant hand.
5. With the guidewire in the trachea, remove the needle.

VIDEO 8.1 Open cricothyrotomy via bougie guidance.

Source: Weingart, S. (2015). *EMCrit Wee—Mind blowing cricothyrotomy* [Video]. https://emcrit.org/emcrit/real-surgical-airway

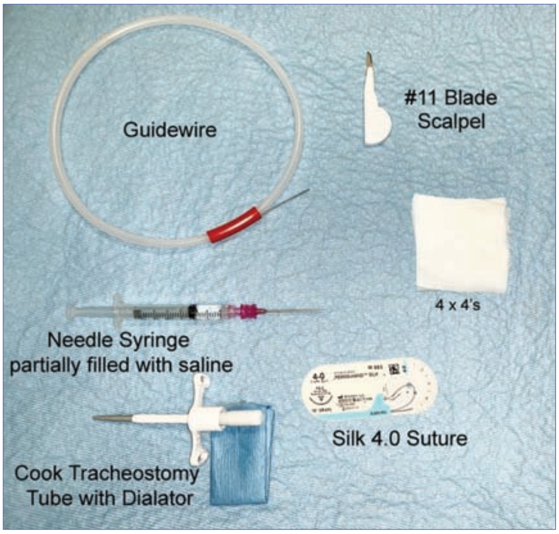
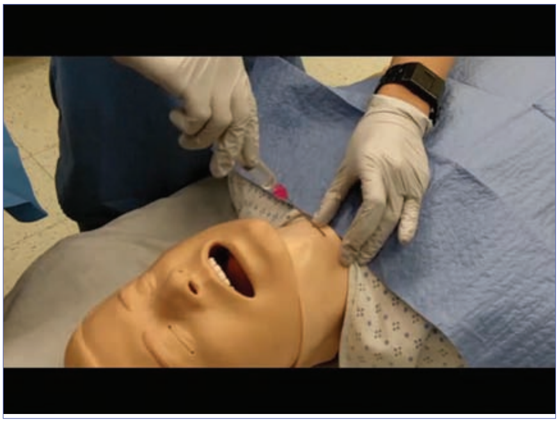

Guidewire
#11 Blade Scalpel
4 x 4's
Needle Syringe partially filled with saline
Silk 4.0 Suture
Cook Tracheostomy Tube with Dialator

FIGURE 8.19 Cook large-caliber percutaneous Seldinger kit.



VIDEO 8.2 Large-caliber percutaneous Seldinger approach shown on manikin.

Source: Reproduced with permission from Canares, T., Valente, J. Rhode Island Hospital, Brown University, published by Medscape Drugs & Diseases. (2020). Surgical Airway Techniques. Retrieved from https://emedicine.medscape.com/article/80241-overview

6. Use the scalpel to nick the skin at the junction of the guidewire and the skin to facilitate the passage of the tracheostomy tube and dilator.
7. Thread the tracheostomy tube and dilator as one unit over the guidewire using a twisting motion, holding its most distal point with the dominant hand.
8. Confirm correct placement with end-tidal capnography and by auscultation of equal bilateral breath sounds.
9. Suture and secure the tracheostomy tube.

SMALL-CALIBER PERCUTANEOUS APPROACH/NEEDLE CRICOTHYROTOMY/TRANSTRACHEAL JET VENTILATION (TTJV) TECHNIQUE

Equipment (**FIGURE 8.20**):

- 14-gauge angiocatheter
- 3- or 5-cc syringe partially filled with saline
- 3.0-ETT adapter cap

Procedure:

1. Identify and palpate landmarks.
    a. It is preferable to confirm with ultrasound.
2. Insert the angiocatheter through the CTM; air aspiration bubbles through the saline confirm entry into the airway.
3. Remove the syringe and withdraw the needle while advancing the catheter in a caudal direction into the trachea.
4. Attach the top adapter from a 3-mm ETT to the angiocatheter.
5. Connect the ventilator (or bag-valve device) to the adapter (**VIDEO 8.3**).

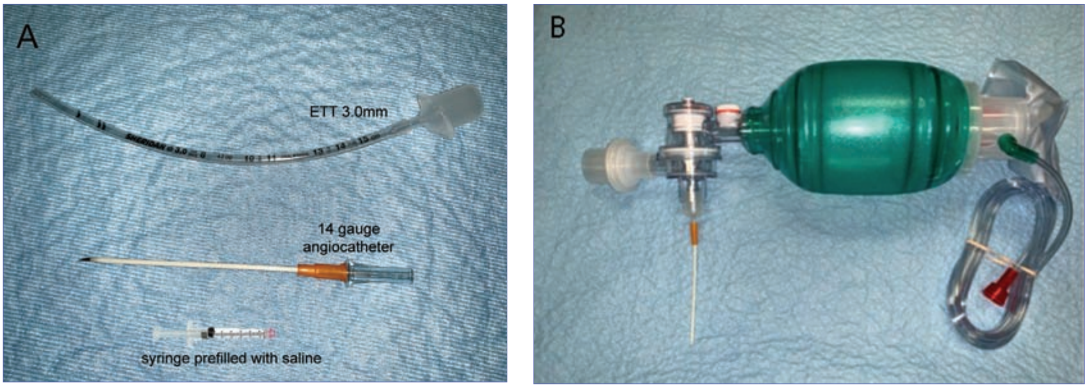
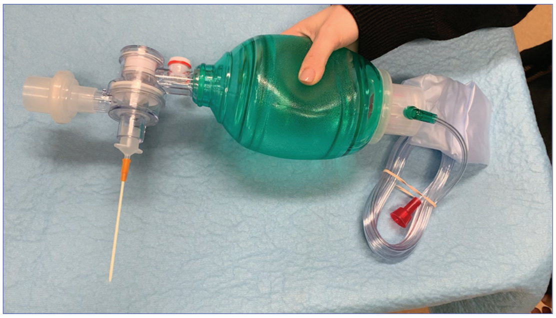


FIGURE 8.20 (A) Angiocatheter and (B) use of a 3.0-ETT adapter cap with a BVM.
BVM, bag-valve mask; ETT, endotracheal tube.



VIDEO 8.3 Percutaneous needle cricothyrotomy using a 14-gauge catheter, adapter cap from a 3-0 ETT, and a bag–valve mask. This is a temporizing procedure in order to bridge the patient to the operating room for a formal open cricothyrotomy or tracheostomy. Note there is a considerable rate of barotrauma and device failure associated with this technique.

NOTE **Ventilation is limited by the diameter of the catheter, allowing for oxygenation/ventilation for only about 30 minutes prior to conversion in the OR to a formal open cricothyrotomy or tracheotomy. Because of this, one may need to decrease the inspiration (I)-to-expiration (E) ratio time (increase the E time relative to the I time).**

POSTPROCEDURE CONSIDERATIONS

As with other methods of intubation, after the cricothyrotomy is performed, the following postprocedure tasks should be completed:

- Verify tube placement.
- Properly secure the tube.
- Address paralysis and/or sedation as indicated based on the specific clinical scenario.
  - Have a low threshold for paralyzing these patients so as to decrease chances of dislodgement.
- Continue diagnostic workup as indicated.

EDUCATIONAL POINTS

- A difficult airway is encountered when a clinician trained in airway management experiences difficulty with BVM ventilation, tracheal intubation, or both.
- The "failed airway" has been traditionally defined in the literature as the inability to achieve successful intubation with three attempts; however, this is simply a failure to intubate.
  - A *failed airway* is better defined as the inability to ventilate via any means.
- A cricothyrotomy should be performed in the "can't intubate, can't ventilate" scenario.
- Learn all methods to cricothyrotomy:
  - Open
  - Seldinger
  - Angiocatheter
- A surgical cricothyrotomy can be performed using several specialized instruments, but may also be performed with a scalpel and an ETT alone.
- The use of a tracheal hook allows one to stabilize the larynx and visualize the opening of the trachea.
- In patients in whom the anatomy cannot be easily palpated (e.g. obesity, short neck, neck swelling), a long midline longitudinal incision should be made to facilitate accurate identification of the CTM.
- A failed intubation is not synonymous with a failed airway.
- The inability to ventilate via any means defines a failed airway and immediate cricothyrotomy is indicated.

COMPLICATIONS

Immediate

- False passage of the tube, most commonly subcutaneous placement
- Misplaced incision with incorrect placement of tube through the thyrohyoid (thyroid) membrane
- Iatrogenic injury to the thyroid or cricoid cartilage
- Posterior tracheal laceration
- Retrograde intubation
- Mainstem intubation
- Aspiration of blood or vomitus
- Occlusion of the tube with blood or vomitus
- Hemorrhage/hematoma

Long Term or Delayed

- Subglottic stenosis
- Brantigan and Grow (1976) showed a low complication rate in 655 patients undergoing cricothyrotomy, with only 0.01% of patients eventually developing subglottic stenosis

ACKNOWLEDGMENTS

We acknowledge Dr. Steven Popoff for providing access to the Lewis Katz School of Medicine, Human Anatomy Lab, which provided Figures 8.8 to 8.14.

PEARLS

- Mental preparation as well as equipment preparation are key.
- While multiple techniques have been described, learning the anatomy is most important in terms of success for this infrequently performed, high-stakes procedure.
- If advanced equipment is lacking, realize that the most basic of supplies can result in a favorable outcome (**FIGURE 8.21**).
- The perception is that a Seldinger cricothyrotomy would be more successful and less time-consuming than an open cricothyrotomy; the literature has suggested the opposite.
- The Fourth National Audit Projects (NAP4) audit in the United Kingdom found a 60% failure rate for emergency percutaneous Seldinger cricothyrotomy, whereas surgical open cricothyrotomy was almost universally successful.
- Paix et al. (2011) has shown that the traditional open surgical cricothyroidotomy procedures are faster than percutaneous Seldinger counterpart techniques, with the average speed 83 ± 44 seconds (range, 28–149 seconds).
- In hypoxic/nonventilated conditions, time is brain; a small randomized controlled trial (RCT) with an animal lab has shown that a BACT is faster than the standard open technique (67 vs. 149 seconds) with less failure (1/10 vs. 3/11).
- Be wary of a potential difficult airway once one of the following occurs:
  - Hypoventilation
  - Hypoxia
  - Hypotension
- The first indication of poor ventilation is a drop in $ETCO_2$; this occurs before a decrease in O_2 saturation and even in chest movement.
  - No one managing an airway can do so without monitoring the quantitative $ETCO_2$.
- In general, open cricothyrotomies are bloody; once the initial incision is made, feel for the CTM, horizontally incise it, and place something in it.

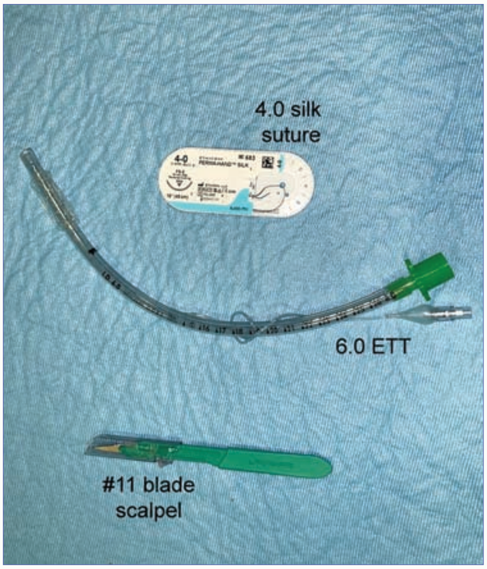


FIGURE 8.21 The most minimal of equipment required for a cricothyrotomy. If there is a bougie present, place the bougie first and slide the ETT over it using the Seldinger technique.

ETT, endotracheal tube.

RESOURCES

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UNIT IV

Procedures for the Heart and Lungs

CHAPTER

9

Pneumothorax

Kimon L. H. Ioannides, Megan Algeo, and Michael Farney

BACKGROUND

Pneumothorax can be one of the most acutely life-threatening conditions in medicine, and diagnosis cannot be missed by anyone; furthermore, treatment is a core competency for an emergency medicine clinician. A pneumothorax, more commonly known as a *collapsed lung*, is caused by the presence of air in the pleural cavity. Between the lungs and the chest wall sits a two-layered membranous sac (pleura membrane), which is responsible for keeping the lungs inflated and aids respiration. Typically, this sac is filled with only a small amount of lubricating fluid, so any air inside is abnormal. Pneumothoraces can occur spontaneously or as the result of trauma, in both healthy and diseased lungs.

Spontaneous pneumothoraces are thought to stem from very small defects in the lung (bleb) parenchyma that allow air to leak into the pleural space. They are further subdivided into primary spontaneous pneumothorax (PSP) in patients without lung disease and secondary spontaneous pneumothorax (SSP) in patients with underlying lung problems (e.g., emphysema) predisposing them to develop such perforations. PSP is classically most common in tall, thin patients who smoke tobacco, and is more than twice as common in men than women. SSP is around half as frequent in absolute terms, but poses a significant threat to chronically ill patients with comorbid conditions, specifically diseased alveoli. Patients at highest risk for SSP include those with chronic obstructive pulmonary disease (COPD, including emphysema), cystic fibrosis (CF), tuberculosis, lung cancer, and a variety of other inflammatory and infectious conditions, notably the *Pneumocystis jirovecii* pneumonias associated with HIV infection (formerly termed Pneumocystis carinii *pneumonia*, or PCP).

Traumatic pneumothorax is among the most common significant injuries in both blunt and penetrating trauma to the chest, and can be caused by infiltration of air into the pleural space either directly from the outside air through the chest wall, or through parenchymal injury. It can also be caused iatrogenically during common procedures such as biopsy, thoracentesis, central-line placement, or positive pressure ventilation.

Anatomy and Physiology

In a spontaneously breathing patient, the chest wall and diaphragm work to increase the volume of the chest during inspiration. The intercostal muscles connect the ribs together, surround the neurovascular bundles located just below each rib, and work together with other chest wall muscles to draw out the ribs (**FIGURE 9.1**). Meanwhile, the diaphragm contracts inferiorly, flattening its natural “inverted U” shape. Together, these create a negative intrathoracic pressure that is transmitted through the pleura to draw air into the lungs. Air entrained between the parietal pleura and the viscerala pleura into the pleural space (a pneumothorax) compromises the body’s ability to expand and ventilate the lungs by impairing the transmission of negative pressure onto the lung’s outer surface, and also reduces the space available for lung expansion.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

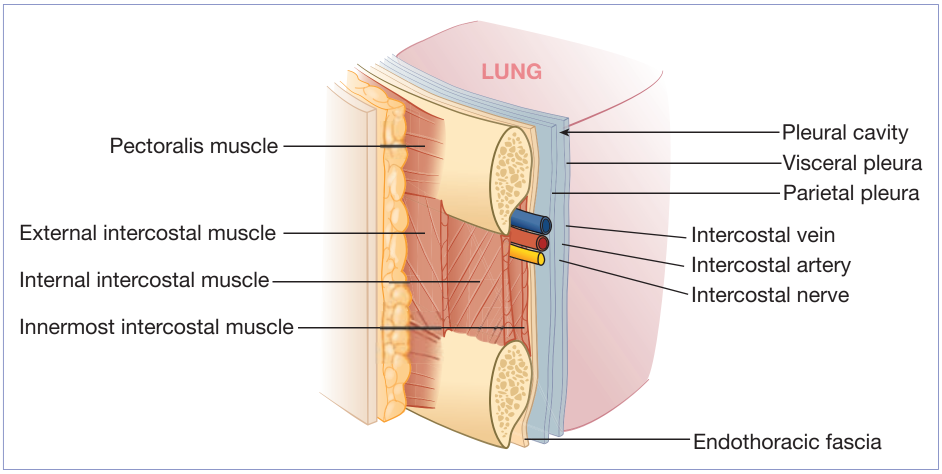

LUNG
Pectoralis muscle
External intercostal muscle
Internal intercostal muscle
Innermost intercostal muscle
Pleural cavity
Visceral pleura
Parietal pleura
Intercostal vein
Intercostal artery
Intercostal nerve
Endothoracic fascia

FIGURE 9.1 Thoracic wall layers.

Tension Pneumothorax

In certain circumstances, notably after trauma, if a flap of tissue creates a "one-way valve" that allows air to enter but not exit the pleural space, air can rapidly enter into the pleural cavity, building pressure (increasing with each breath) without a way to leave, creating what is known as a *tension pneumothorax*. This flap consists of chest wall tissue that allows outside air into the pleura without a way to escape, which is known as a *sucking chest wound*. This is compounded in patients on positive pressure ventilation, who are already at higher risk of pneumothorax. Tension physiology can lead not only to a rapidly expanding pneumothorax, but also create enough pressure to impede venous return to the chest or push the mediastinum across the midline (**FIGURE 9.2**). This distorts the structure of the great vessels and further limits venous return, potentially leading to hypotension, hypoxia, and cardiovascular collapse.

- A tension pneumothorax is thus an immediately life-threatening condition and requires emergent treatment.
- Among patients being ventilated with positive pressure, tension physiology can develop especially rapidly, likely presenting with hypotension instead of hypoxia.

Although typically identified with upright chest radiography, in supine patients, chest x-ray is less reliable (**FIGURE 9.3**).

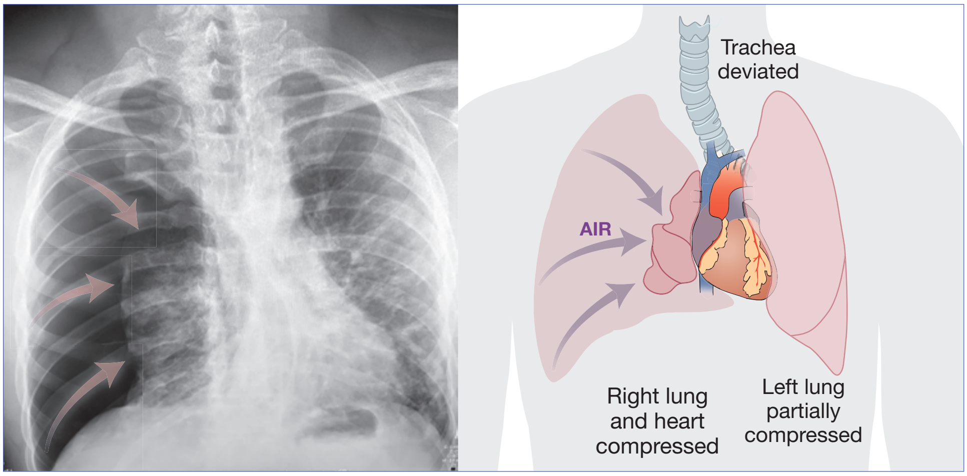

Trachea deviated
AIR
Right lung and heart compressed
Left lung partially compressed

FIGURE 9.2 Tension pneumothorax. Note increasing intrathoracic pressure and extrinsic kinking of the SVC and IVC leads to a decrease in preload and impedance of cardiac output, with the sequala of hypotension (obstructive cardiogenic shock).

IVC, inferior vena cava; SVC; superior vena cava.

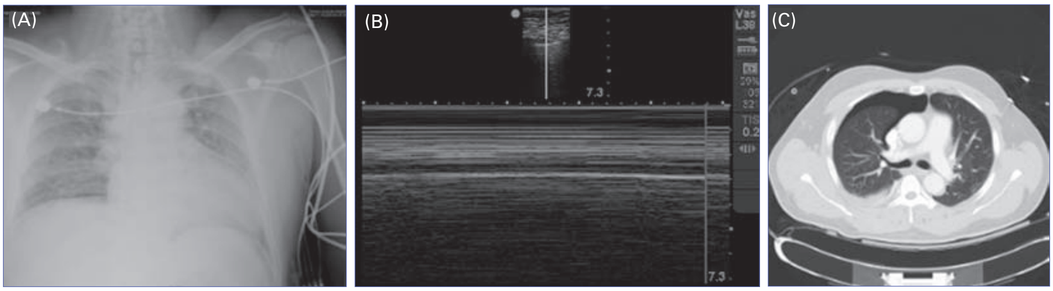


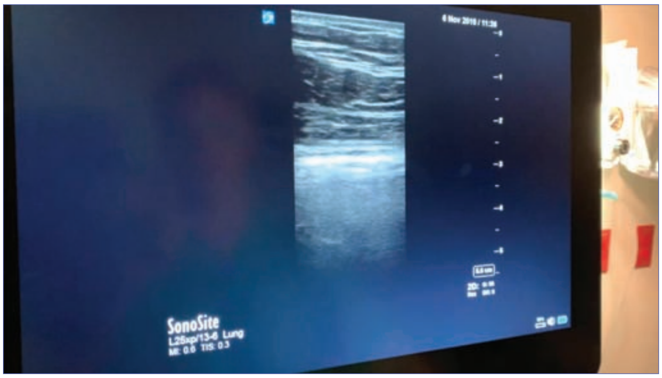
FIGURE 9.3 Imaging of a pneumothorax. (A) Supine CXR appearing normal. (B) Lung ultrasound showing barcode sign (see below). (C) CT image confirming pneumothorax.

CXR, chest x-ray.

- Wilkerson and Stone (2010) reviewed four prospective studies (606 patients) and noted that the sensitivity of a supine anteroposterior chest x-ray (AP CXR; typically utilized in the evaluation of the traumatic patient) displayed a sensitivity of detecting a pneumothorax at 28% to 75%, whereas point-of-care ultrasound (POCUS) was 86% to 98%.
- Alrajab et al. (2013) have shown that for pneumothorax:
  - POCUS has a pooled sensitivity of 78.6% and a specificity of 98.4%.
  - CXR has a pooled sensitivity of 39.8% and a specificity of 99.3%.

Ultrasonography utilizes characteristic signatures of pleura and lung tissue to aid in the rapid diagnosis of life-threatening pneumothorax at the bedside. Normally, the visceral pleura (which adhere to the outer surface of the lungs) slide continuously and smoothly against the parietal pleura (which adhere to the inner wall of the chest **FIGURE 9.4**). Just deep to the pleura lies air contained in alveoli interspersed with small septae.

Under sonography, air creates a reverberation artifact, so normal lung sliding between parietal and visceral pleura creates a continuously varying image between septal and air-containing areas known as *lung sliding* under B-mode (**VIDEO 9.1**) or a *seashore sign* under M-mode (see **FIGURES 9.4** and **9.6**).



VIDEO 9.1
B-mode point-of-care ultrasound showing normal lung via lung sliding.

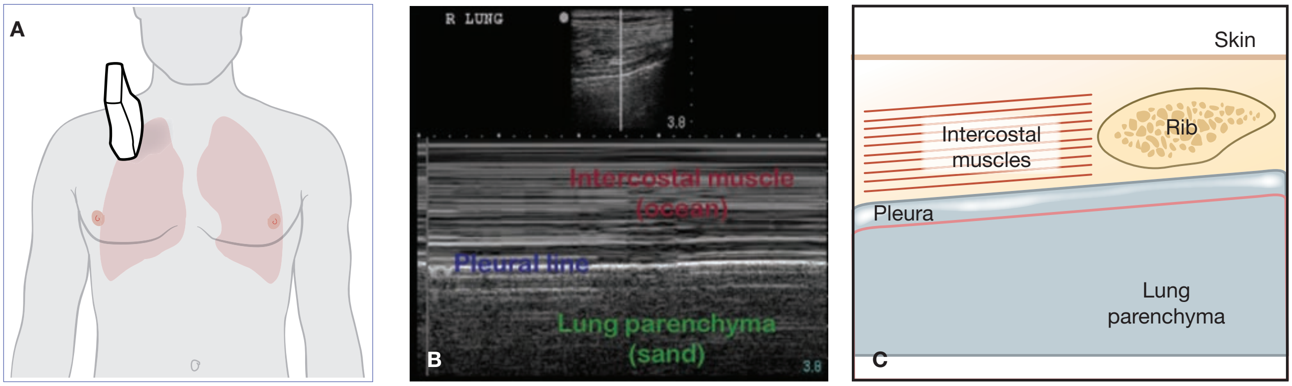


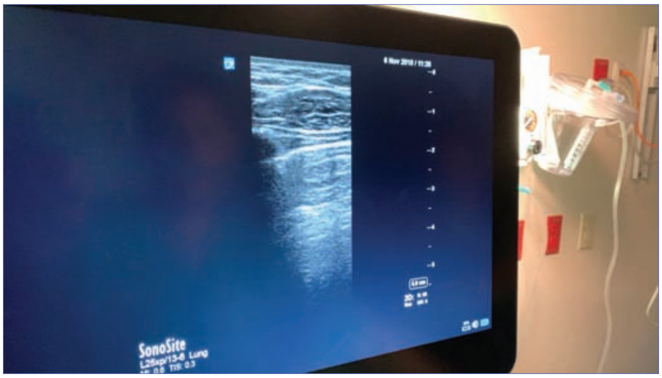
FIGURE 9.4 Seashore sign of normal visceral–parietal pleura lung sliding on M-mode sonography.

Source: Costantino, T., & and Gibbons, R.

In contrast, pneumothorax causes a more stable air artifact known as a *barcode sign* under M-mode and under B-mode there is absence of lung sliding (**FIGURE 9.5** and **VIDEO 9.2**). The presence of lung sliding has shown a diagnostic accuracy approaching that of CT scans. See **FIGURE 9.6** for a comparison of M-mode POCUS showing normal lung (no pneumothorax) displaying a seashore sign and abnormal (pneumothorax) displaying a barcode sign.

Two rare causes of pneumothorax that illustrate important principles of chest anatomy deserve mention here:

- Infection by air-producing organisms in the pleural space can entrap air directly or erode through lung parenchyma.
- Noppen (2010) describes a clinical scenario in which the negative pressure created by the chest wall can extend below −54 mmHg during very vigorous inspiration, enough to bring gases dissolved in body tissues out of solution, whose total partial pressure is typically 706 mmHg, and cause a gradually growing pneumothorax. Conversely, restoration of more normal negative pressures (typically in the single digits) can lead to gradual dissolution of intrapleural air into the surrounding tissues and resolution of any pneumothorax.



VIDEO 9.2
B-mode point-of-care ultrasound showing a pneumothorax via absent lung sliding.

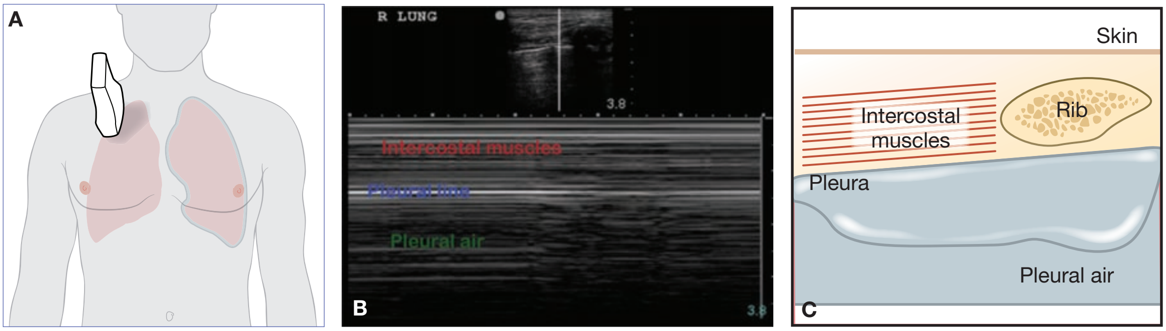

A
R LUNG
3.8
Intercostal muscles
Pleural line
Pleural air
B
3.8
Skin
Intercostal muscles
Rib
Pleura
Pleural air
C

FIGURE 9.5 Barcode sign of pneumothorax on M-mode sonography. Note that patient moved slightly halfway through the exam, and the slightly wavy area is from this movement. Note that still air (air in the pleura sac) is stable/not moving and hence displays linear constant returns.

Source: Costantino, T., & Gibbons, R.

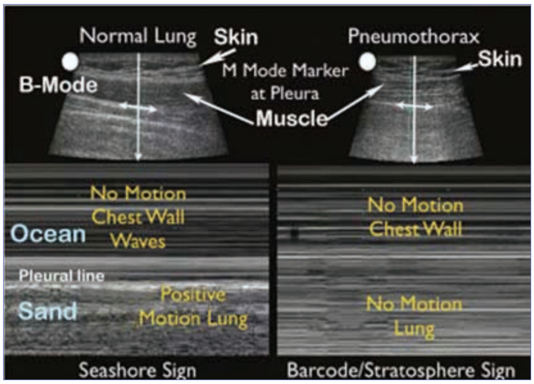

Normal Lung
Skin
Pneumothorax
Skin
B-Mode
M Mode Marker at Pleura
Muscle
No Motion Chest Wall
Ocean Waves
Pleural line
Sand
Positive Motion Lung
No Motion Chest Wall
No Motion Lung
Seashore Sign
Barcode/Stratosphere Sign

FIGURE 9.6 M-mode point-of-care ultrasound showing normal lung (no pneumothorax) displaying seashore sign and abnormal lung (pneumothorax) displaying barcode sign.

PATIENT PRESENTATION

Pneumothorax encompasses a wide spectrum of disease, with a correspondingly broad range of patient presentations. Otherwise healthy patients with PSP will typically complain of unilateral chest pain (air in the normally airless pleura hurts!), dyspnea, or cough. They may not show classic findings of tachypnea, tachycardia, or desaturation, but most often will demonstrate unilaterally decreased breath sounds. SSP is more likely to present with hypoxia (impaired parenchyma to begin with), but diagnosis of these patients is often confounded by their underlying lung disease.

Traumatic pneumothorax should be suspected in all patients with penetrating thoracic trauma to the chest, upper and middle back, inferior neck, and superior abdomen and flanks. It should be suspected as well in any severely ill blunt-trauma patient, particularly if chest or back pain, dyspnea, hypoxia, abnormal breath sounds, rib fractures, or obvious signs of trauma to the chest wall are present.

Pneumothorax can easily be missed in elderly or substantially injured multisystem trauma patients, and can present in a delayed fashion, particularly after intubation or application of positive pressure ventilation (creates higher airway pressures). Empiric treatment is required prior to definitive diagnosis in many such cases. Concurrent vascular injuries to the lung are also common, and can lead to hemothorax (blood in the pleural cavity). When present with pneumothorax, this condition is known as *hemopneumothorax*, and is treated in a similar manner with pleural drainage.

TREATMENT

Once identified, treatment of pneumothorax should be tailored according to its severity and etiology. Generally small, asymptomatic, spontaneous pneumothoraces in otherwise healthy patients, especially if discovered incidentally, may simply be observed. On the other hand, large, symptomatic, traumatic, loculated, or complex pneumothoraces complicated by blood, purulent fluid, or preexisting adhesions in the pleura are unlikely to respond to conservative therapy, and will benefit from pleural drainage.

Two separate guidelines have defined the difference of small and large pneumothoraces (**FIGURE 9.7**):

- American guidelines state the cutoff is 3 cm from the pleura to the lung tissue, at the level of the apex.
- British guidelines define the cutoff as 2 cm from the pleura to the lung tissue at the level of the hilum.

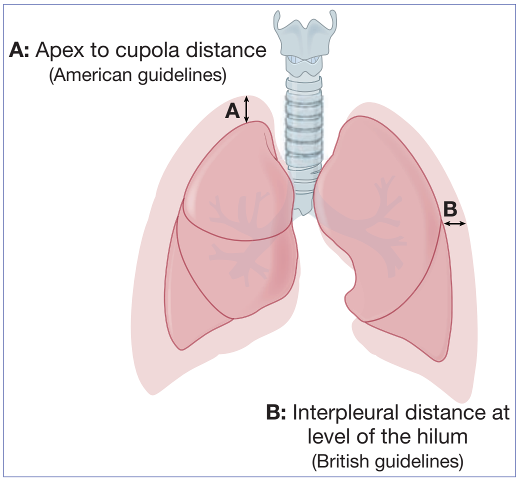

A: Apex to cupola distance
(American guidelines)
A
B
B: Interpleural distance at level of the hilum
(British guidelines)

FIGURE 9.7 Size of pneumothorax. British guideline uses 2 cm, whereas the American guideline uses 3 cm as a distance for differentiating small versus large pneumothoraces.

Subtypes

As stated previously, there are two major subtypes of pneumothorax:

1. Spontaneous (two subtypes)
    a. PSP
        i. Smoking is the highest risk factor and routine smoking cessation is advised.
        ii. Despite general agreement, algorithms vary in regard to the initial management of PSP although the overall consensus is toward more conservative management.
        iii. In a very recent study reported in the *New England Journal of Medicine*, Brown et al. (2020) indicated that 316 patients with a moderate-to-large pneumothorax (≥32%) studied at 39 hospitals were randomly assigned to a conservative or an interventional approach.
            1) In the conservative-management group, patients were observed for at least 4 hours in the ED and then, if repeat chest radiographs showed no enlargement and the patients did not need oxygen and could walk without difficulty, they were discharged with written instructions and analgesia to be followed as outpatients.
            2) In the intervention group, a small-bore Seldinger-type chest tube (less interventional than what is routinely used) was placed and attached to a water seal for 1 hour; if the lung had reexpanded and there was no air leak, the tube was clamped for 4 hours and, if the lung remained fully expanded, the chest tube was removed and the patient was discharged; in both groups, if the pneumothorax grew, the patient was admitted to the hospital for pleural drainage.
            3) Almost 85% of the patients in the conservative-management group did not undergo any intervention and had full reexpansion within 8 weeks; these results were noninferior to those in the intervention group.
            4) Conservative management resulted in:
                a) Fewer hospitalization days
                b) Fewer days off work

        c) A lower likelihood of prolonged chest-tube drainage
        d) Less need for surgery
        e) Fewer adverse events and fewer serious adverse events than interventional management
            i) *Most of the complications came from the chest drains themselves.*
        f) The percentage of patients with early pneumothorax recurrence and over the next 12 months was also lower in the conservative-management group
            i) *Authors hypothesized that a possible explanation is that chest-tube drainage interfered with healing by pulling open the defect in the lung, whereas allowing the lung to reexpand slowly on its own permitted the defect to heal.*
    b. SSP
        i. Pleural drainage as initial treatment
2. Traumatic pneumothorax
    a. Trauma
        i. Treatment dictated by stability of patient and size of pneumothorax
    b. Iatrogenic
        i. Treatment dictated by stability of patient and size of pneumothorax

Management

According to recent literature, management is less dependent on size, and is more dependent upon:

- Subtype
- Patient stability
    - PSP management—Stable patients with initial, primary, spontaneous pneumothoraces, regardless of size, may be observed.
        - There is a paucity of literature looking at treatment of primary pneumothorax with O_2 therapy versus room air, none of which are recent studies.
            - In 1983, Chadha and Cohn looked at a trial of high-flow O_2 therapy in PSP patients, and showed that in a pneumothorax of less than 30% O_2 therapy increased the rate of resolution three-fold compared to room air observation though the *n* was small.
        - Vuong et al. (2018) looked at 29 randomized clinical trials (4,262 patients) and found that simple needle aspiration (NA) alone resulted in the same recurrence rate as compared to tube thoracostomy or video-assisted thoracoscopic surgery (VATS) in regard to recurrence rate.
        - If pneumothorax is small and patient is asymptomatic, simple observation is needed for 3 to 6 hours and, if no progression of size or symptoms, patient may be discharged with follow-up the next day for a repeat CXR.
        - NA via 14-/16-gauge needle is as effective as large-bore (>20-French size) chest drains and may be associated with reduced hospitalization and length of stay.
        - Following failed NA, small-bore (<14-French size) pneumothorax catheter insertion is recommended.
        - Large-bore chest tube (LBCT) drains are generally not needed for the initial treatment of pneumothoraces.
        - If this is a reoccurrence, then pleurodesis (chemically induced via a sclerosing agent, joining of the parieal and visceral layers) is recommended.
    - SSP management—Secondary spontaneous pneumothoraces, regardless of size and patient's medical stability, should be treated with thoracostomy and admitted.
    - Traumatic pneumothorax management
        - Treatment depends upon size and patient stability.
        - Any patient with a traumatic pneumothorax being intubated (positive-pressure ventilation [PPV]) requires catheter/tube thoracostomy.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- In some patients with known coagulopathies, for example, significant thrombocytopenia or supratherapeutic anticoagulant use, the risks and benefits of thoracostomy should be carefully weighed, but the procedure is never absolutely contraindicated.

SPECIAL CONSIDERATIONS

- Although many patients with PSP can occasionally be discharged home with a one-way Heimlich valve, patients with questionable follow-up should be admitted to the hospital for management of their pneumothorax.

- Hassani et al. (2009) retrospectively evaluated an ED-based, outpatient approach to the management of PSP using a small-bore catheter attached to a Heimlich valve and noted that 42 of 62 cases (68%) were successfully treated without any further intervention; they showed that this approach compared favorably to the traditional approach of using large-bore chest tube attached to wall suction and hospital admission.
- Temple University Department of Emergency Medicine wrote a most comprehensive review (Repanshek et al., 2013). Specifically, their recommendation in regard to postprocedural care states:

  > Discharge after placement of a small-bore catheter with a Heimlich valve is contingent upon a CXR demonstrating reexpansion, the resolution of symptoms, and reliable follow-up. Different studies on the subject matter have advocated repeating radiography at 3–4 hours or 4–6 hours, with discharge and ambulatory treatment if re-expansion is achieved. All studies recommend daily follow-up for repeat imaging, highlighting the importance of reliability as a necessity for discharge. There is differing opinion on the appropriate length of time to wait before removal of catheter. In one study, the valve was closed after 6 or 7 days of treatment and removed if there was no evidence of persistent pneumothorax or air leak. Another recommends a minimum of 2 days of treatment, at which point the valve can be closed and repeat imaging done 4–6 hours later, with removal of catheter if re-expansion is maintained. This study suggests a longer treatment period for larger and recurrent pneumothoraces. Finally, in yet another study, patients received a repeat CXR 1 hour after catheter placement. If there was re-expansion, the valve was closed and this was repeated after another 4–6 hours. If the lung remained expanded, the catheter was removed, the patient was discharged home, and a follow-up CXR study was obtained 24 hours later. Failure of reexpansion using Heimlich valve generally requires catheter attachment to a pleural drainage system and hospital admission. Persistent and recurrent pneumothorax may necessitate large tube thoracostomy and potentially, surgical intervention. For patients in whom reexpansion is achieved using small-bore catheter, we recommend discharge with Heimlich valve if the patient is able to have reliable follow-up at 24 and 48 hours for repeat imaging [(**FIGURE 9.8**)]. Alternatively, in ED settings in which time allows, an asymptomatic patient may be observed for a minimum of 4 h and then have a repeat chest x-ray study done. If no recurrence is seen, the catheter may be removed and the patient discharged with follow-up in 24 hour. (pp. 464–465)

TECHNIQUES

Common techniques in emergent settings include placing either a small-bore catheter through a percutaneous Seldinger technique, a small-bore Intro-Tip catheter, or a larger bore chest tube of up to 40-French size with an open technique.

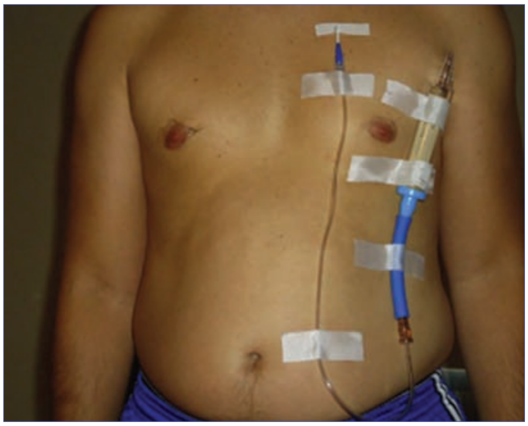


FIGURE 9.8 Ambulatory Heimlich valve placement for outpatient management.

1. Spontaneous pneumothorax—Although the conventional method has been the use of large-bore tubes, recent literature has favored small-bore catheters as the primary treatment modality in primary and secondary spontaneous pneumothoraces. Failure rate between the two is equal in both groups, but the duration of drainage, length of hospital stay, and complication rate are all lower with small-bore catheters.
   - Chang, Kang, Chiu, and Chiu (2018) in a meta-analysis of 11 studies with a total of 875 patients investigated the effectiveness of small-bore pigtail catheter (PC) drainage compared with that of LBCT drainage as the initial treatment approach for all subtypes of pneumothorax, and found the success rate was similar in both groups.
     - Success rate was similar in the PC (79.8%) and LBCT (82.9%).
     - PC drainage was associated with a significantly lower complication ($OR = 0.49$) rate.
     - In the spontaneous subgroup, PC drainage was associated with a significantly shorter:
       - Drainage duration (mean difference, 1.51 days)
       - Hospital stay (mean difference, 2.54 days)
     - They concluded that PC drainage may be considered as the initial treatment option for patients with primary or SSP, acknowledging that randomized controlled trials are needed to compare PC versus LBCT among different subgroups of patients with pneumothorax.
2. Traumatic pneumothorax
   - Bauman et al. (2018) retrospectively reviewed 496 patients with traumatic pneumothoraxes and showed that small-bore catheters are the same as large-bore catheters with regard to failure rate, complications, and initial drainage output, though this study was not randomized and therefore selection bias occurred.

  - Tanizaki et al. (2017) retrospectively looked at 124 traumatic pneumothoraces treated with small (20–22-French size) versus large (28-French size) and found there was no significant difference in the primary outcomes of tube-related complications, duration of tube, need for additional tube placement or thoracostomy; they concluded that in the traumatic pneumothorax patient, a small tube size is as efficacious as a large one.

Certain conditions may warrant a large-bore tube thoracostomy because of its greater and faster draining capacity:

- Large air leaks
- Empyema
- Hemothorax
- Barotrauma
- Tension pneumothorax

Regardless of the choice of drainage catheter, the fundamental steps and principles of the procedure remain relatively the same.

PROCEDURE

The most important step prior to chest drainage is assessment of the severity of the pneumothorax. Rapidly decompensating patients may benefit from immediate decompression, even without a definitive diagnosis of pneumothorax. For example, needle or finger thoracostomy may be lifesaving in a hemodynamically unresponsive or cyanotic patient with penetrating chest trauma, or in a mechanically ventilated patient with unexplained sudden hypoxia or increased peak pressures. In these cases, treatment should not necessarily be delayed by concern for full sterility of the procedure and can be bilateral if the laterality of the pneumothorax cannot be confirmed. Certainly POCUS can and should be utilized if nearby, as this diagnostic test takes seconds.

Needle Thoracostomy (Decompression and Aspiration)

Needle thoracostomy can be subdivided into two entities:

- Needle decompression
  - Used for quick correction of tension pneumothorax and acts as a bridge until a catheter/tube thoracostomy can be placed.
- Needle aspiration
  - Used for PSP and may be the definitive treatment.

Some controversy exists over the optimal location and device to choose for needle thoracostomy. As the prevalence of obesity increases, more patients have thicker chest walls and hence a 5-cm catheter may not penetrate the second intercostal space (ICS), which is the traditional midclavicular line. The fourth ICSs at the anterior or middle axillary line, the traditional locations for chest catheter/tube placement, have been advanced as more effective alternatives (**FIGURE 9.9**).

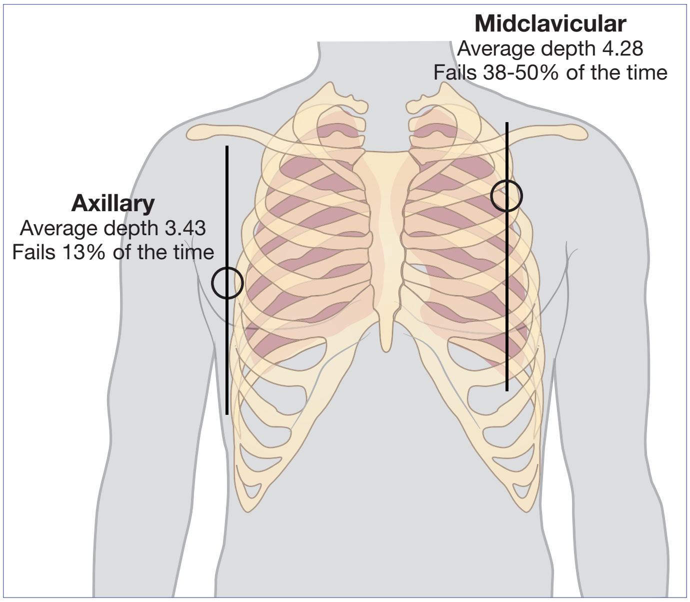


FIGURE 9.9 For needle decompression, use the anterior axillary line fourth ICS entry point.
ICS, intercostal space.

- Laag et al. (2016) in a meta-analysis looked at chest needle decompression with a 5-cm angiocatheter as related to chest wall thicknesses and found the following (see **TABLE 9.1**).
- Evidence from other observational studies also suggests that the fourth ICS at the anterior axillary line has the lowest predicted failure rate of needle decompression in multiple populations.

TABLE 9.1 Chest Needle Decompression With a 5-cm Angiocatheter as Related to Chest Wall Thicknesses and Failure Rates

Variables	Anterior Axillary Line	Midaxillary Line	Midclavicular Line
Chest wall thickness	3.43 cm (fourth ICS)	3.98 cm (fourth ICS)	4.28 cm (second ICS)
Failure rate (%)	13	31	38

ICS, intercostal space.

Needle Decompression Steps

Needle decompression is simple to perform for rapid correction of tension pneumothorax.

1. Cleanse (if time permits) and expose the chest wall.
2. An intravenous catheter, traditionally a 5-cm 14-gauge angiocatheter, is placed perpendicularly through the skin in the fourth ICS at the anterior axillary line (traditionally the midclavicular line, see previous text), just superior to the fifth rib (**FIGURE 9.10A**).
3. The catheter is advanced until the hub meets the skin, or until a rush of air is appreciated. The needle is subsequently withdrawn, leaving the catheter secured to the chest wall (**FIGURE 9.10B**).

Needle Aspiration Steps

NA is simple to perform for rapid correction of PSP.

1. Cleanse and expose the chest wall.
2. An intravenous catheter, traditionally a 5-cm 14-gauge angiocatheter, is placed perpendicularly through the skin in the fourth ICS at the anterior axillary line (see **FIGURE 9.9**).
3. The catheter is advanced until the hub meets the skin, or until a rush of air is appreciated. The needle is subsequently withdrawn, leaving the catheter held secure to the chest wall via the nondominant hand.
4. A three-way stopcock can then be added to the end of the catheter and a syringe subsequently added to that (**FIGURE 9.11**).
5. To further aspirate air after initial decompression, draw back on the syringe, close the stopcock, remove the syringe, and release air from the syringe.
6. Reattach the syringe and open the stopcock to repeat this step.

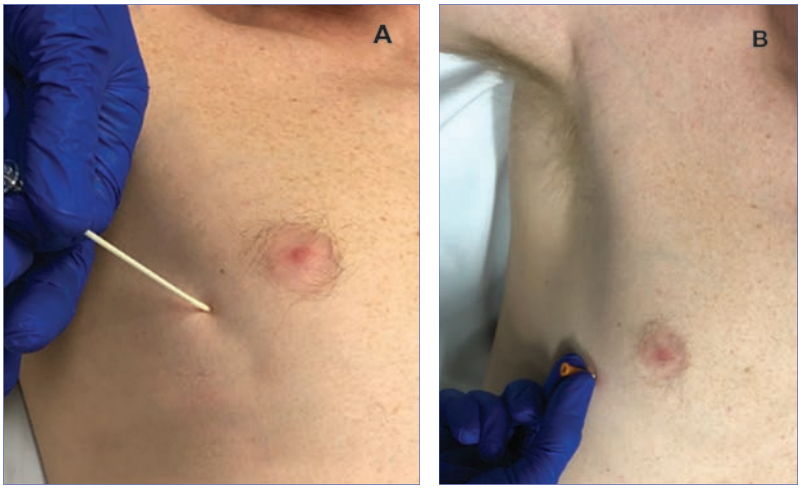


FIGURE 9.10 (A) Needle decompression for a suspected tension pneumothorax. Use a 5-cm 14-gauge angiocatheter at the anterior axillary line fourth/fifth ICS. (B) A rush of air should be appreciated. Place angiocath all the way in until the hub rests on the skin.

ICS, intercostal space.

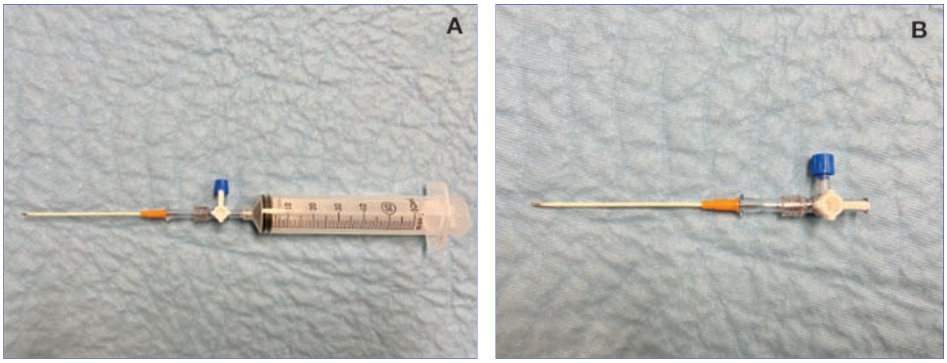


FIGURE 9.11 (A) A 5-cm 14-gauge needle attached to a three-way stopcock and 60-mL syringe; the clinician simply aspirates 60 mLs of air.
(B) Syringe is removed and the stopcock turned to the "off" position to prevent room air from reentering the pleural cavity while the clinician rids the hub of air.

Preparation: Small-Bore/Large-Bore Tube Thoracostomy

Catheter/tube thoracostomy begins with careful preparation of the patient and collection of all required materials. In cases in which an unstable patient may need immediate decompression, written informed consent may be deferred; all other cases should have written consent.

1. If the patient is awake, local anesthesia is essential and systemic analgesia is recommended in order to control pain for most patients. Acknowledging the plethora of choices, in stable patients the authors favor a 1-mcg/kg bolus of intravenous fentanyl in addition to local anesthesia via lidocaine or bupivacaine with epinephrine.
    a. Local anesthesia should be distributed widely in the skin, soft tissue, and intercostal muscle layers along the intended path (**FIGURE 9.12**).
    b. Infiltration should extend to at least the depth of the rib by impacting it with the needle tip, so a 5-cm or longer needle may be required in obese patients.
    c. Whenever possible, the periosteum and parietal pleura should be infiltrated and anesthetized as well.
2. Full sterile precautions should be used, including sterile gloves, gown, mask, and hair net.
3. The patient should be positioned supine with the body straight and resting at the edge of the bed; the arm of the affected side is abducted beyond 90 degrees, ideally with enough external rotation to place the palm of the hand on the back of the head (**FIGURE 9.13**).
    a. The patient's wrist can be loosely taped to the head of the bed in order to maintain the position.

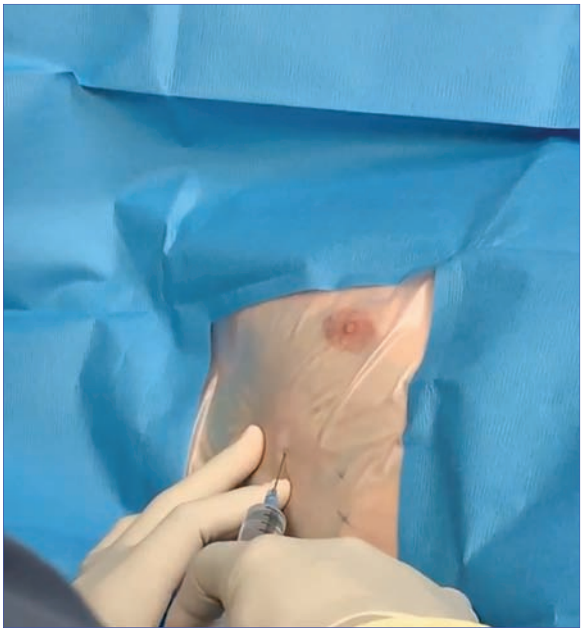


FIGURE 9.12 Local anesthetic for tube thoracostomy.

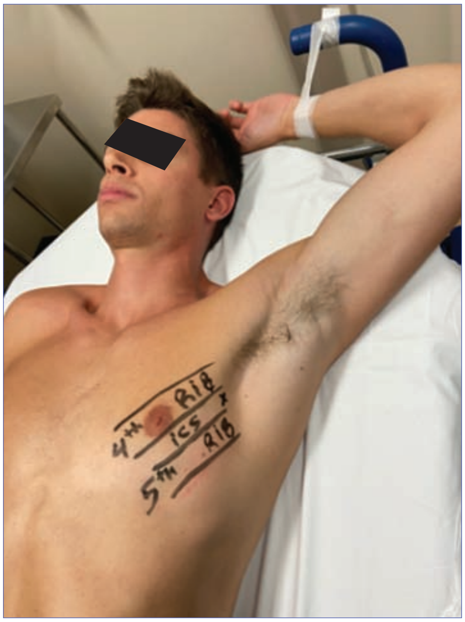


FIGURE 9.13 Outlined is the fourth and fifth rib, and the fourth ICS. Catheter/tube thoracostomy (represented by the X) is recommended at the anterior axillary line in the fourth ICS, just superior to the fifth rib.

ICS, intercostal space.

4. The chest should then be exposed and widely prepped with iodine- or chlorhexidine-based cleaning solution.
5. The intended puncture site should be marked, typically in the fourth ICS, slightly superior to the fifth rib, at the anterior axillary line, often just lateral to the nipple or the inframammary fold.
    a. By an entry point superior to the rib, one attempts to avoid the neurovascular bundle that resides in the intercostal groove at the inferior margin of each rib (see **FIGURE 9.1**).
6. Skin prep should then extend across to the midline of the chest from the sternal notch down to the inferior aspect of the thoracic cage, back to the posterior axillary line, and up to the axilla.
7. Surgical towels or a drape can then be used to establish a sterile field for the procedure.
8. Select desired size thoracostomy catheter/tube; recent literature shows that there is equal efficacy for large-bore and small-bore devices in traumatic and secondary spontaneous pneumothoraces.

Small-Bore Seldinger Technique Tube Thoracostomy Supplies

- Iodine- or chlorhexidine-based cleaning solution (**FIGURE 9.14**)
- Lidocaine or bupivacaine with epinephrine drawn up in a 10-mL syringe with 23-gauge needle
- Sterile gloves, gown, mask, and hair net
- Sterile surgical drapes or towels
- 4 × 4 gauze pads
- 4 × 4 drain sponges
- No. 11 scalpel
- Needle attached to syringe
- Small-bore chest tube (<22-French size)/PC
- Guide wire
- Dilator(s)
- One-way Heimlich valve or water-seal apparatus (**FIGURE 9.15**)
- Connecting tube with closed drainage system
- 0 silk suture
- Needle safety holder
- Tape
- Petroleum-impregnated gauze
- Sterile gauze
- Quick Fix adhesive dressing

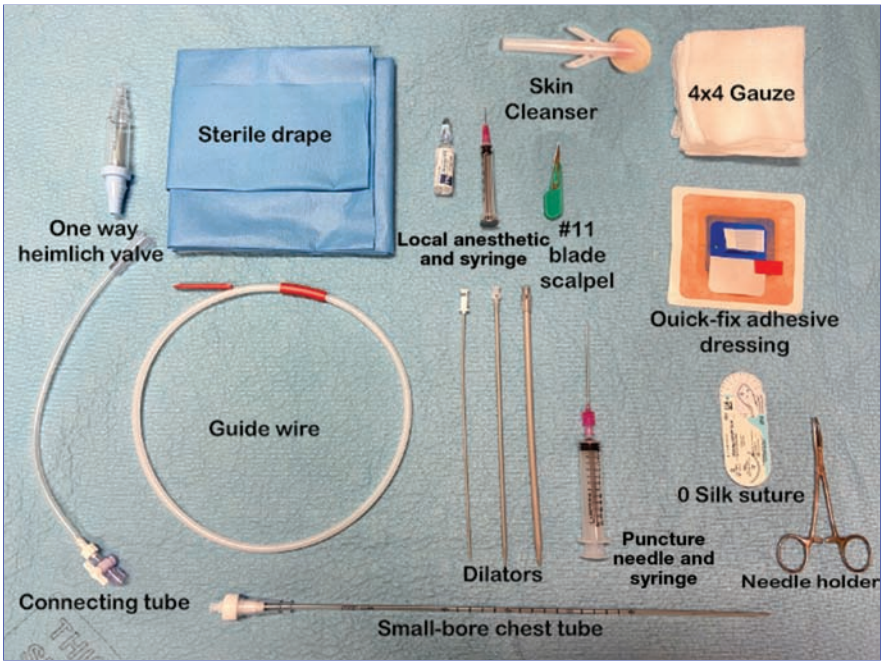

Sterile drape
Skin Cleanser
4x4 Gauze
One way heimlich valve
Local anesthetic and syringe
#11 blade scalpel
Quick-fix adhesive dressing
Guide wire
0 Silk suture
Puncture needle and syringe
Dilators
Needle holder
Connecting tube
Small-bore chest tube

FIGURE 9.14 Seldinger technique tube thoracostomy supplies.

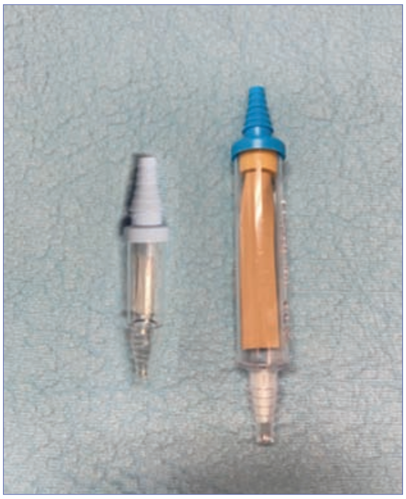


FIGURE 9.15 One-way Heimlich valves. Attach the thoracostomy tube to the colored end of the valve if a water-seal apparatus is not needed (smaller leaks). Note that when air passes through the distal end of the Heimlich valve, a characteristic flutter sound may be heard.

Small-Bore Seldinger Technique Tube Thoracostomy Steps

1. Insert needle with syringe plunger attached into the fouth ICS anterior axillary line. Feel for the fifth rib before inserting and guide the needle on top of the rib with the vector of the needle toward the axillae (**FIGURE 9.16** and **VIDEO 9.3**). Continue until the parietal pleura is penetrated by a rush of air.
   a. One can use POCUS to get a definitive distance from skin to pleura.
2. Remove the syringe. Straighten the guide-wire tip and insert into the needle (**FIGURE 9.17**). Advance the wire approximately 4 cm past the needle tip and do not withdraw the wire.
3. Remove the needle while maintaining a strong grip on the guide wire to ensure the wire is stationary (**FIGURE 9.18**).
   a. **Never let go of the guide wire.**
4. To open the surrounding skin, make a small cut with the scalpel, directed away from the wire (**FIGURE 9.19**).
5. Gently insert the smallest dilator over the guide wire and, using a firm distal grip, rotate in clockwise and counterclockwise directions to help ease and expand the dilator through the tissue (**FIGURE 9.20**). Always start with the smallest dilator and keep replacing the dilator over the same wire with the next largest size, ending by removing the final (largest) dilator off the guide wire.
   a. Dilators do not/should not be inserted fully, just through the parietal pleura.
   b. **Never let go of the guide wire.**
6. Straighten the final small-bore tube or PC, and insert over the guide wire as the skin has now been sufficiently dilated secondary to repetitions performed in step 5 (**FIGURE 9.21**). Advance a few centimeters past the porous portion of the tube.

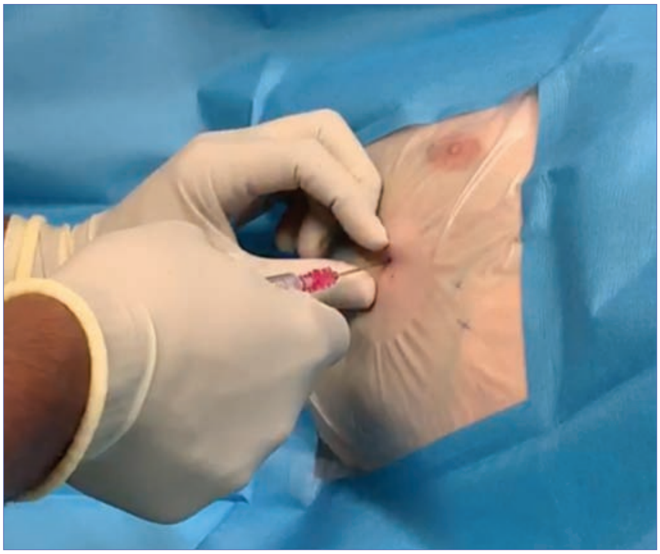
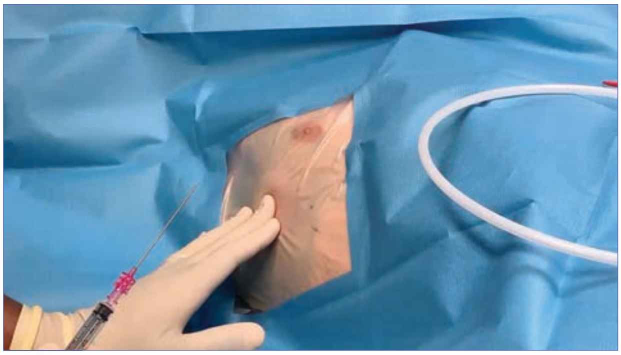


FIGURE 9.16 Needle insertion.



VIDEO 9.3 Seldinger technique for tube thoracostomy.

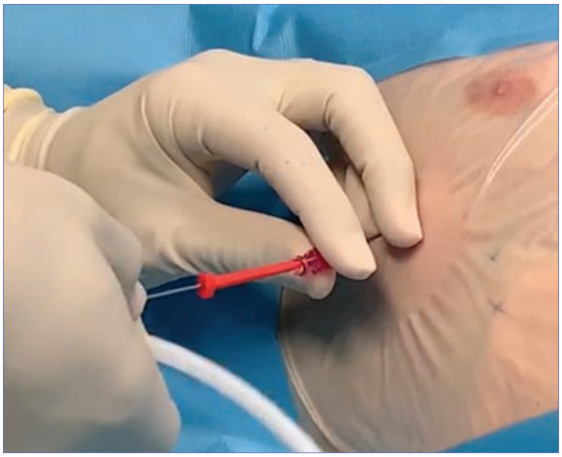


FIGURE 9.17 Guide-wire insertion.

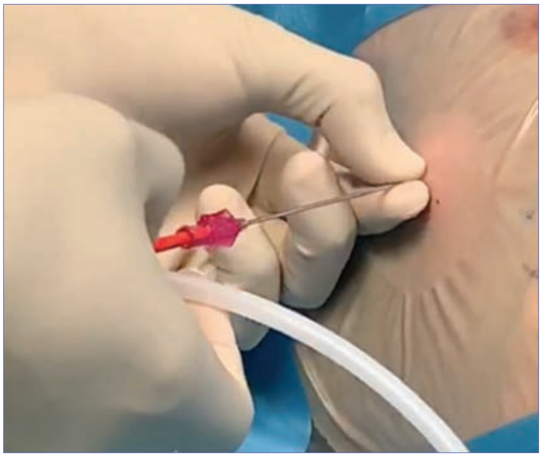


FIGURE 9.18 Needle removal.

FIGURE 9.19 Incise the skin just through the dermis with scalpel.

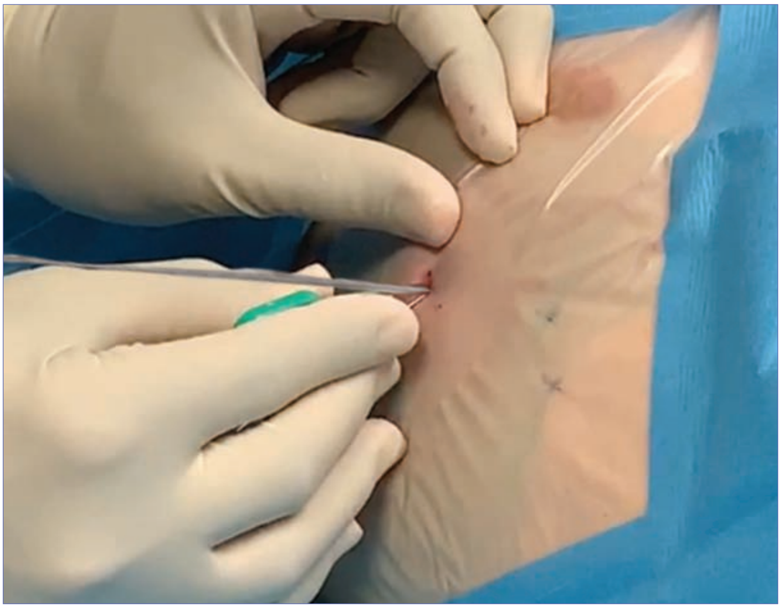


FIGURE 9.20 Dilator insertion. Note the nondominant hand is holding the distal end of the guide wire (not seen).

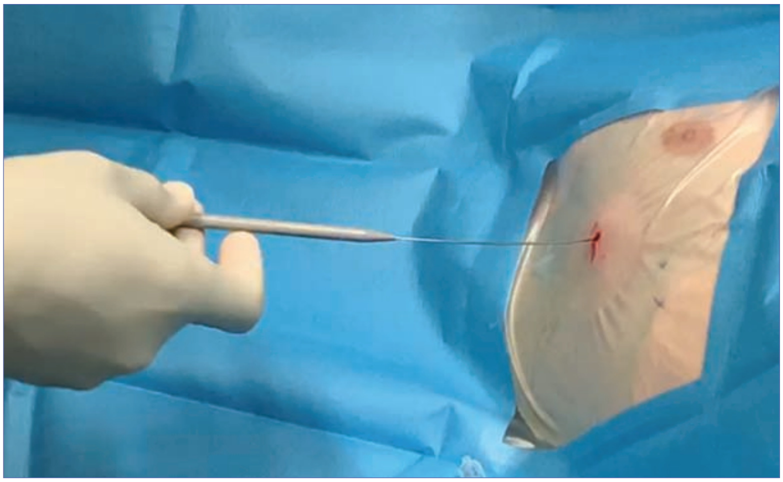
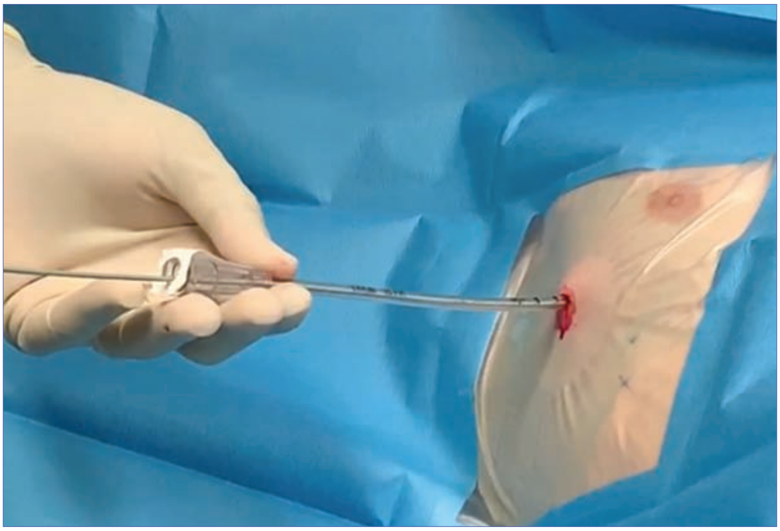


FIGURE 9.21 Small-bore chest tube is inserted over the guide wire after progressive dilation.



7. Connect the tube to the one-way Heimlich valve or water-seal apparatus.
    a. The clinician can have the patient take a full tidal volume breath in and out and watch the one-way valve flap to see whether the tube is functioning properly and likewise look for air bubbles from the water-seal device.
8. The tube can then be secured using a 0 silk suture.
    a. One such technique uses an interrupted suture through the skin tied alongside the tube, with both tails of suture then wrapped around the chest tube in a tight overlapping clockwise and counterclockwise fashion (with at least four loops, two from each strand) and again knotted tightly together to secure the tube.
9. If there are concerns as to the placement of the tube, while maintaining sterility, a portable chest x-ray can ideally be performed at this stage to verify that the pneumothorax is substantially decompressed, and the tube is in place; if it is not, the tube can then be manipulated or resecured, still under sterile conditions, until acceptable resolution is noted.
10. Once a tube thoracostomy has been sutured and secured, petroleum-impregnated gauze can be placed surrounding the tube on all sides, both along its 360-degree circumference and superficially.
11. Sterile split drain sponges (split 4 × 4s) should then be placed to cover the impregnated gauze, and generous strips of tape used to cover the dressing on all sides. Kits may come with a prepackaged securing device that may be used in lieu of self-fashioned gauze.
    a. As an alternative to the petroleum, drain sponges, and tape, commercially prepared all-in-one devices, such as Quick Fix, simplify this step and are effective (**FIGURE 9.22**).

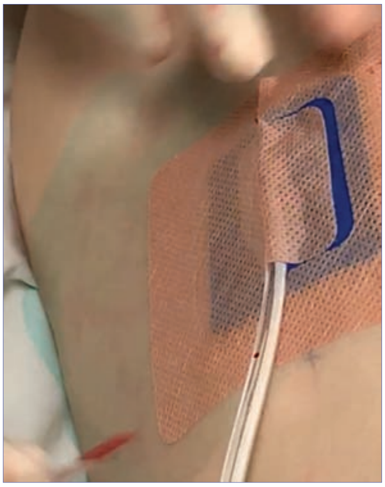


FIGURE 9.22 Quick Fix all-in-one pneumothorax catheter adhesive dressing.

Note simplicity, sturdiness, and patient comfort.

Small-Bore Intro-Tip Catheter Thoracostomy Supplies

- Iodine- or chlorhexidine-based cleaning solution (**FIGURE 9.23**)
- Lidocaine with epinephrine drawn up in a 10-mL syringe with a 23-gauge needle
- Sterile gloves, gown, mask, and hair net
- Sterile surgical drapes or towels
- 4 × 4 gauze pads
- No. 11 scalpel
- "Intro Tip" catheter (**FIGURE 9.23** detail)
- One-way Heimlich valve or water seal apparatus (see **FIGURE 9.15**)
- Connecting tube with closed drainage system
- 0 silk suture
- Needle safety holder
- Tape
- Petroleum-impregnated gauze
- Quick Fix adhesive dressing

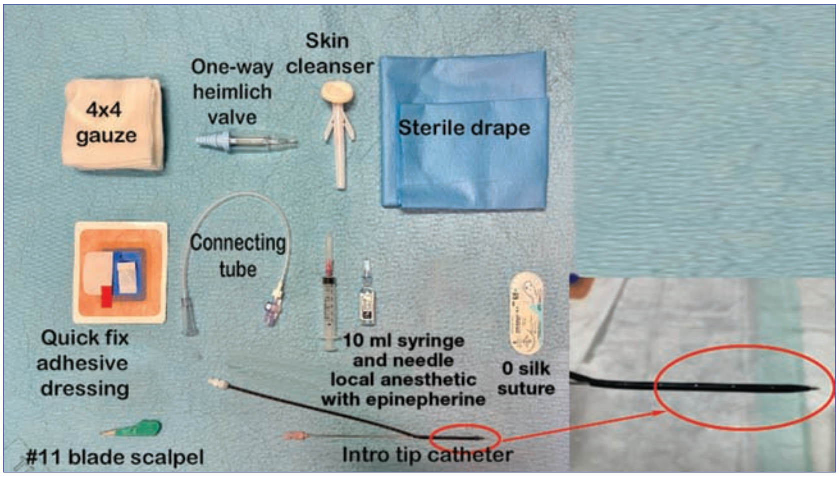


FIGURE 9.23 Intro Tip catheter thoracostomy supplies. Note Intro Tip detail.

Small-Bore Intro Tip Catheter Thoracostomy Steps

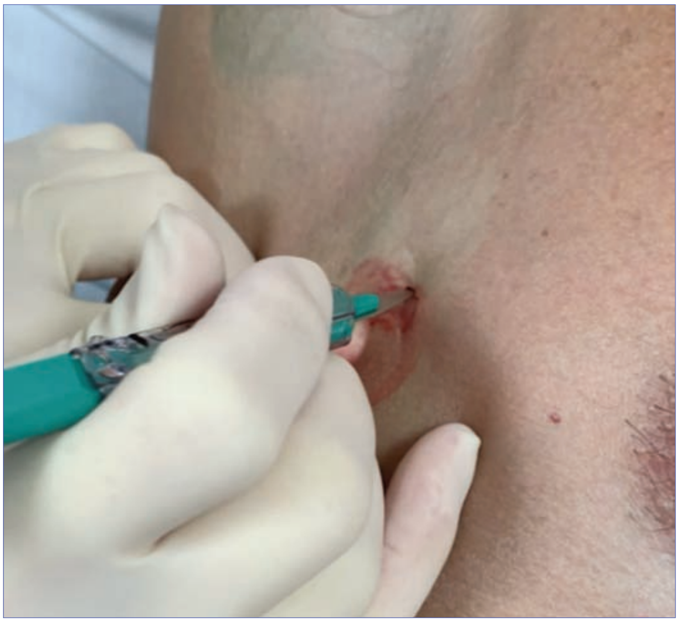


FIGURE 9.24 Slit over insertion site.

1. Use scalpel to make small slit at the desired insertion site over the top of the fifth rib in the fourth ICS (**FIGURE 9.24** and **VIDEO 9.4**).
2. Insert Intro Tip needle into the slit and advance the needle/guide wire gliding over top of the rib, angling superiorly toward the apex of the lung (**FIGURE 9.25**).
3. After entering the pleural space (rush of air and/or POCUS-measured distance past the parietal pleura) remove the needle and advance the catheter. Connect the catheter to the one-way Heimlich valve or water-seal apparatus (**FIGURE 9.26**)
    a. The provider can have the patient take a full tidal volume breath in and out and watch the one-way valve flap to see whether the catheter is functioning properly and likewise see any air bubbles coming from the water-seal device.
4. The catheter can then be secured using a 0 silk suture.
    a. We favor a simple interrupted suture through the skin tied alongside the catheter, with both tails of suture wrapped around the chest catheter in a tight overlapping clockwise and counterclockwise fashion (with at least four loops, two from each strand) and again knotted tightly together to secure the catheter.
5. If there are concerns as to the placement of the catheter, while maintaining sterility, a portable chest x-ray can ideally be performed at this stage to verify that the pneumothorax is substantially decompressed, and the catheter is in place. If it is not, the catheter can then be manipulated or resecured, still under sterile conditions, until acceptable resolution is noted.

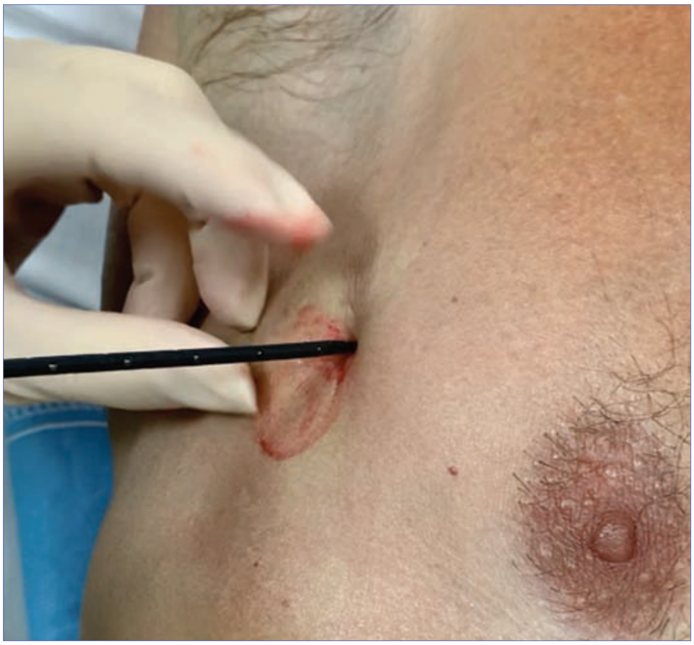
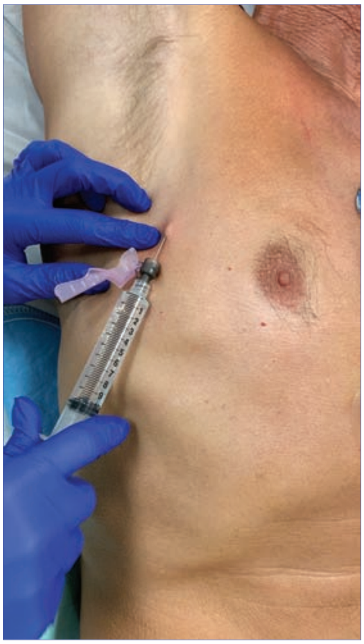


FIGURE 9.25 Intro Tip insertion.



VIDEO 9.4 Small-bore Intro Tip needle thoracostomy.

6. Once a catheter thoracostomy has been sutured and secured, petroleum-impregnated gauze may be placed surrounding the catheter on all sides, both along its 360-degree circumference and superficially.
7. Sterile gauze with split 4 × 4 drain sponges should then be placed to cover the impregnated gauze, and generous strips of tape used to cover the dressing on all sides. Kits may come with a prepackaged securing device that may be used in lieu of self-fashioned gauze.
    a. As an alternative, a Quick Fix adhesive-dressing device may be used in lieu of traditional 4 × 4 gauze and tape (**FIGURE 9.27** and **VIDEO 9.5**).

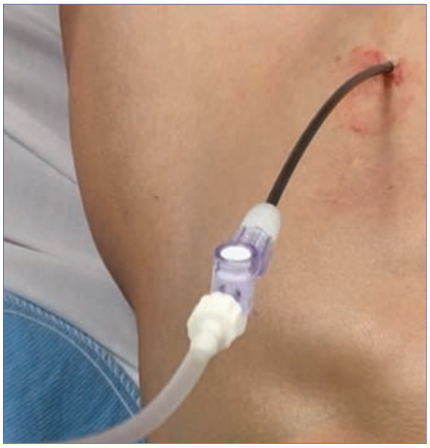


FIGURE 9.26 Small-bore Intro Tip catheter thoracostomy. Note small skin/soft-tissue violation as opposed to a formal large chest tube thoracostomy.

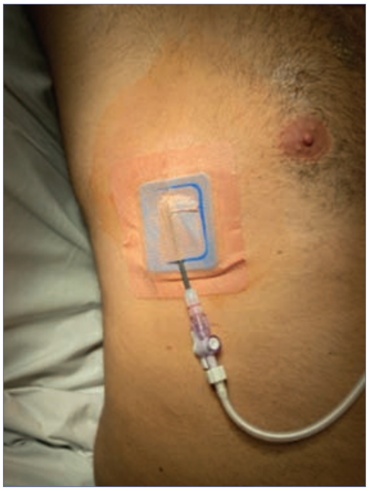


FIGURE 9.27 Quick Fix adhesive-dressing device.

VIDEO 9.5 Quick Fix adhesive-dressing placement.

Large-Bore (Traditional) Tube Thoracostomy Supplies

- Iodine- or chlorhexidine-based cleaning solution (**FIGURE 9.28**)
- Lidocaine with epinephrine drawn up in a 10-mL syringe with a 23-gauge needle
- Sterile gloves, gown, mask, and hair net
- Sterile surgical drapes or towels
- 4 × 4 gauze pads
- Drain sponges (not shown)
- No. 11 scalpel
- Curved Kelly clamp and hemostat clamp
- LBCT (>24-French size)
- One-way Heimlich valve and water-seal apparatus (see **FIGURE 9.15**)
- Connecting tube with closed drainage system
- Needle safety holder
- 0 silk suture
- Petroleum-impregnated gauze
- Sterile gauze
- Tape

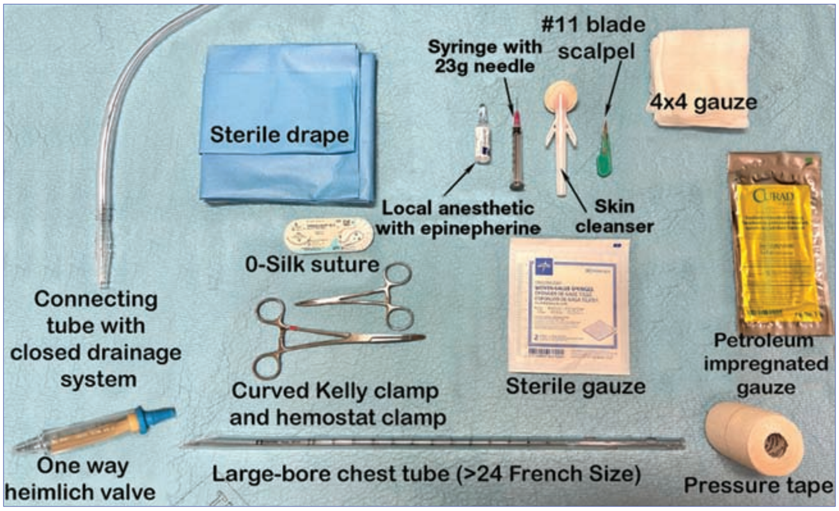

Syringe with 23g needle
#11 blade scalpel
4x4 gauze
Sterile drape
Local anesthetic with epinepherine
Skin cleanser
CURAD
0-Silk suture
Connecting tube with closed drainage system
Curved Kelly clamp and hemostat clamp
Sterile gauze
Petroleum impregnated gauze
One way heimlich valve
Large-bore chest tube (>24 French Size)
Pressure tape

FIGURE 9.28 Large-bore tube thoracostomy supplies.

Large-Bore (Traditional) Tube Thoracostomy Steps

1. After identification of the fourth ICS anterior axillary line, local anesthesia should be distributed widely in the skin, soft tissue, and intercostal muscle layers along the intended path. Infiltration should extend to at least the depth of the rib by impacting it with the needle tip, so a 5-cm or longer needle may be required in obese patients. Whenever possible, the periosteum and parietal pleura should be infiltrated and anesthetized as well.
2. A 2- to 3-cm horizontal incision is then made through the skin with No. 11 scalpel.
3. Through blunt dissection using a curved Kelly clamp, proceed to the rib, and then slide just superior to it until the pleura is reached (**FIGURE 9.29**).
   a. If time allows, we favor continuing to infuse local anesthetic in multiple stages along this tract, especially if the pleura itself can be identified. When possible, tunneling the tract upward through soft tissue for an additional rib space can be helpful in improving the chest tube's seal.
4. The clamp is then used to puncture the pleura itself, resulting in a pronounced pop and rush of air (**FIGURE 9.30**).
5. The clamp can then be expanded slightly and retracted in the partially open position to expand the tract.
6. At this point a gloved finger should be immediately placed through the hole in the pleura to verify that the smooth inner surface of the pleural cavity has been accessed, and that no adhesions or blood clots will block insertion (**FIGURE 9.31**).
   a. Special care, and perhaps use of double sterile gloves, is required with this step to avoid injury to the clinican if a patient has a known or suspected rib fracture around the intended thoracostomy. If possible, areas with rib fractures should be avoided for this reason.
   b. If the procedure ends at this stage, it is known as *simple finger thoracostomy*.
7. If chest tube placement is required, a chest drain should be handled with the Kelly clamp's teeth at the fenestrated tip of the deep end of the drain, with the clamp's handle roughly following the tube's length. The drain can then be occluded near its superficial end with an occluding forcep (**FIGURE 9.32**).
8. Using a finger against the pleura along the anterior aspect of the thoracostomy as a guide, the tube can then be advanced posteriorly and superiorly through the pleura toward the posterior apex of the lung, avoiding the interlobar fissure when possible, ensuring that the final fenestration lies well within the pleural cavity. It should be inserted until the last fenestration is at least 5 cm inside the chest wall.

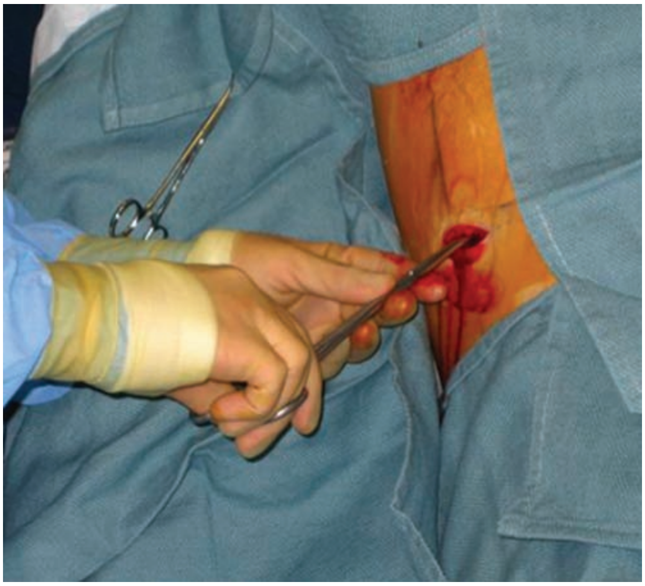


FIGURE 9.29 Blunt dissection down to the intercostal muscle.

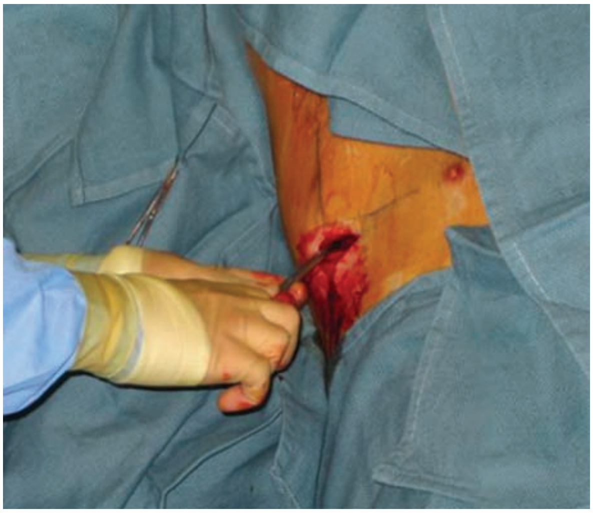


FIGURE 9.30 A closed and locked Kelly clamp is used to enter the chest wall into the pleural cavity. Make sure to guide the clamp over the upper margin of the rib in order to avoid the intercostal vessels, which lie at the inferior aspect of the rib.

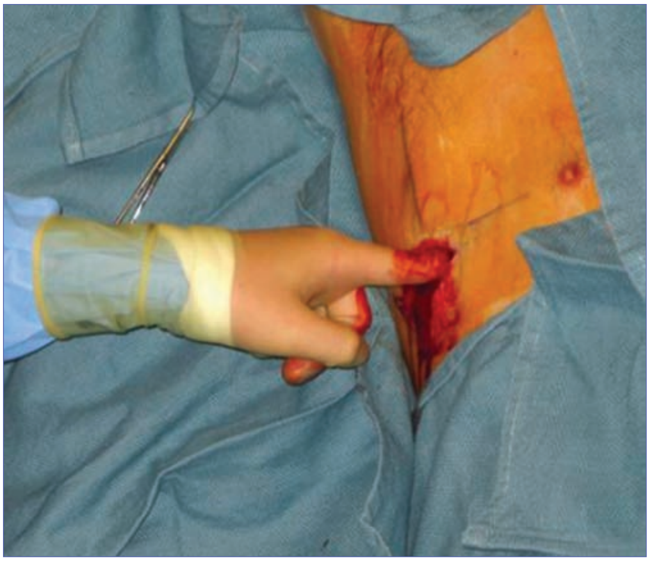


FIGURE 9.31 A finger is used to palpate the tract and feel for adhesions before insertion of the chest tube. Note when the possibility of rib fractures exists, do not use your finger.

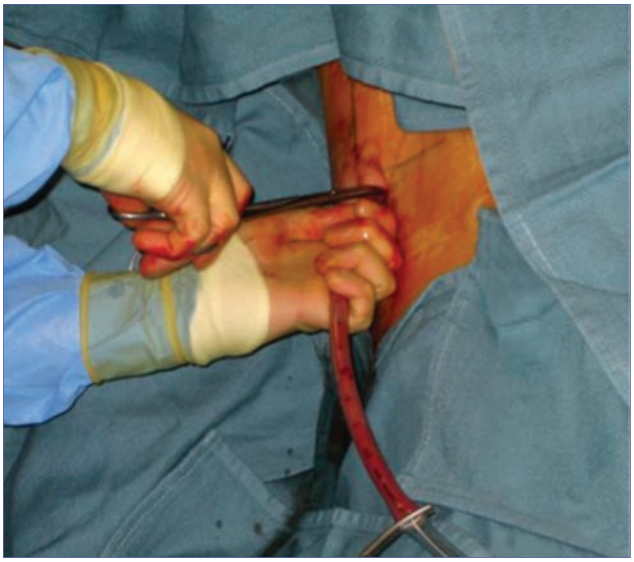


FIGURE 9.32 The proximal end of the chest tube is held with a Kelly clamp that is used to guide the chest tube through the tract.

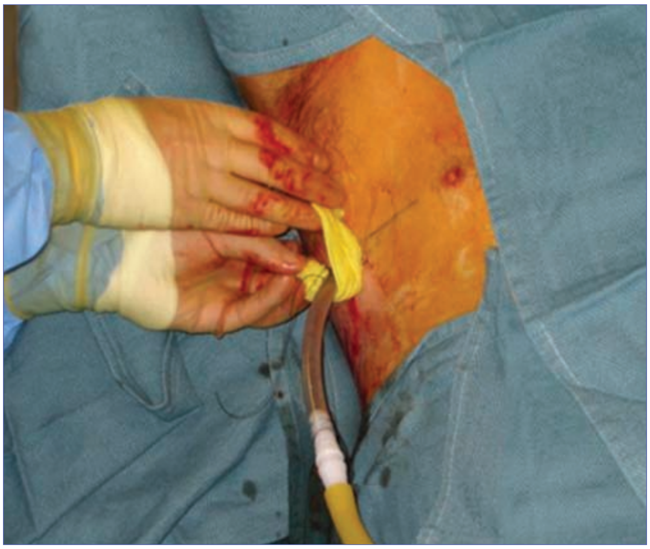


FIGURE 9.33 Apply petrolatum gauze over the skin incision.

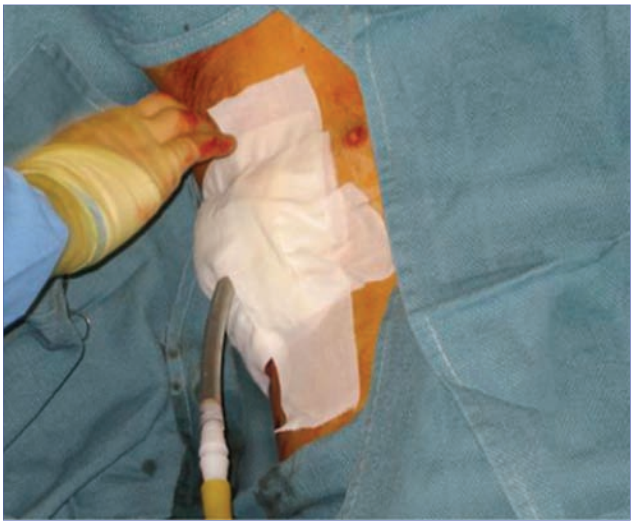


FIGURE 9.34 Apply support gauze dressing around the chest tube and secure it to the chest wall with 4-inch adhesive tape.

9. At this point, the tube should be held firmly and not be released by the clinician at the skin. However, the superficial end of the drain can be attached to a one-way Heimlich valve or water-seal apparatus by a nonsterile assistant.
    a. Proper placement of the thoracostomy can be immediately assessed through the presence of respirophasic fogging in the tube and tidal variation in the water-seal apparatus corresponding to respiratory intrapleural pressures.
10. The tube can then be secured using a 0 silk suture.
    a. We favor a simple interrupted suture through the skin tied alongside the tube, with both tails of suture wrapped around the chest tube in a tight overlapping clockwise and counterclockwise fashion (with at least four loops, two from each strand) and again knotted tightly together to secure the tube.
11. If there are concerns as to the placement of the tube, while maintaining sterility, a portable chest x-ray can ideally be performed at this stage to verify that the pneumothorax is substantially decompressed, and the tube is in place. If it is not, the tube can then be manipulated or resecured, still under sterile conditions, until acceptable resolution is noted.
12. Once a tube thoracostomy has been sutured and secured, petroleum-impregnated gauze should be placed surrounding the tube on all sides, both along its 360-degree circumference, and superficially (**FIGURE 9.33**).
13. Sterile gauze should then be placed to cover the impregnated gauze, and generous strips of tape used to cover the dressing on all sides (**FIGURE 9.34**).

POSTPROCEDURE CONSIDERATIONS

- Pain
- Infections
- Tube dislodgement

COMPLICATIONS

Most complications declare themselves via a lack of air return.

- Tube malposition (most common complication)
    - Trocar technique of chest tube insertion has been shown to increase the risk of tube malposition compared with the blunt-dissection techniques.
    - Tube migrates out of the chest, which may require another thoracostomy to maintain sterility.
    - In general there are four types of migration:
        - Intraparenchymal
            - Pleural adhesions
            - Other pulmonary disease
            - CXR not sensitive for diagnosis
                - CT superior and more sensitive
        - Intrafissural
            - More common in the lateral approach
        - Angulation of the drain in the pleural space
        - Extrathoracic
            - Subcutaneous placement (chest wall)
                - Minimized with blunt dissection
            - Rarely can migrate within the chest (**FIGURE 9.35**)

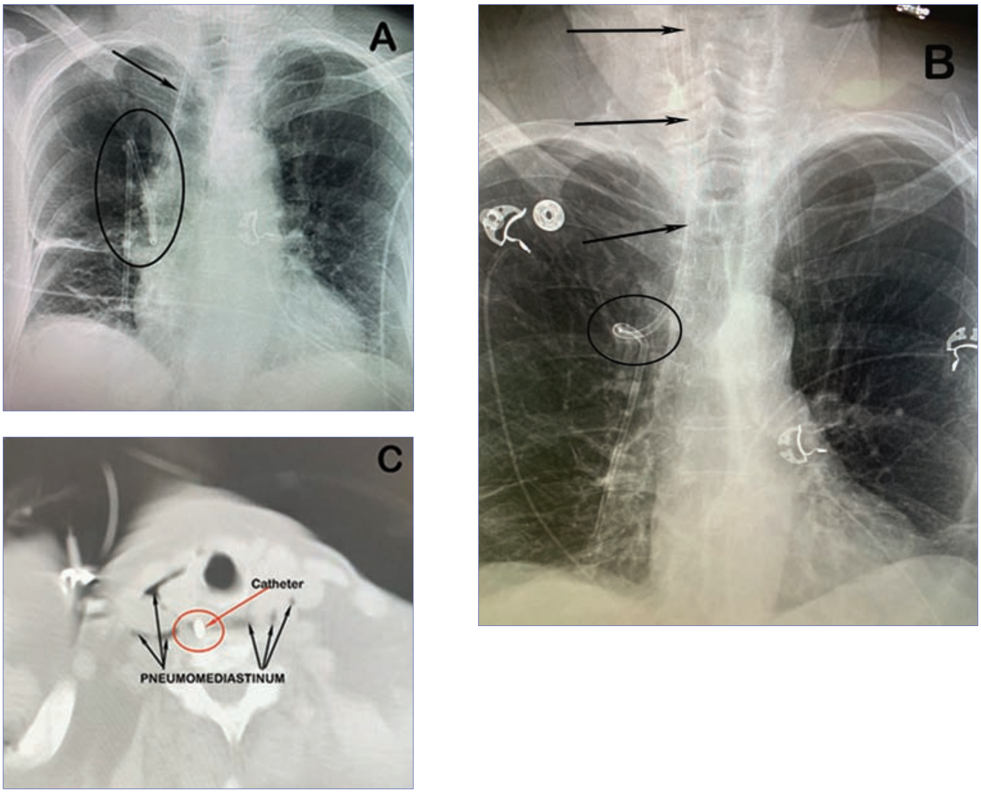


FIGURE 9.35 Patient had a small-bore tube thoracostomy placement with complete resolution of the pneumothorax. A few hours later the patient complained of neck pain. (B) A repeat CXR and later CT of neck and chest show that the catheter migrated from the apical intrapleural space cephalad to the neck in the prevertebral space. Note the large coil configuration in (A) resulted in a kink in the catheter as the catheter migrated through the parietal pleura into the neck. (C) In the axial (transverse) CT image of the neck, the catheter is seen in the prevertebral soft-tissue space as well as the sequela of a pneumomediastinum.

      - Abdominal
        - Use the triangle of safety to safeguard (see Chapter 10)
          - Secondary to being placed too inferiorly
          - Spleen, liver, and stomach placement have all been reported after placement inferior to the diaphragm (**FIGURE 9.36**).
          - This is easily avoided by always choosing a more superior ICS for catheter/tube placement, such as the fourth ICS.
- Blocked tube
  - Kinking (see **FIGURE 9.35A**)
  - Luminal
    - Clot
    - Lung debris
    - Lung tissue
  - A cardinal sign of a blocked chest tube drain is failure of fluid within the tube to fluctuate with coughing or respiration.
  - If an ongoing air leak, a tension pneumothorax can result.
- Hematoma
  - Substantial bleeding may also occur, either as a manifestation of the patient's underlying traumatic injury or as a complication of the procedure, which can injure intercostal or pulmonary vessels.
    - Intercostal artery injury
      - Cause a hemorrhage during the insertion of catheter/tube.
      - Intercostal arteries may bleed profusely when traumatized.
      - Entry points/dissection during catheter/tube insertion should be above the superior border of the rib to avoid the neurovascular bundles on the groove located on the inferior aspect.
    - Internal mammary artery laceration with midclavicular line placement
      - Use anterior axillary line.
    - Pulmonary artery/vein
      - These injuries occurred mainly with the use of Trocar method of chest tube insertion; however, it has occurred following blunt-dissection technique.
      - Usually occurs in the setting of underlying pulmonary pathology, such as dense pleural adhesion in the pleural space or postpneumonectomy states.
      - Dense pleural adhesion prevents the normal entry into the pleural space leading to lung penetration and subsequent perforation of the pulmonary vessel.
      - Diagnosis is made by the immediate return of frank blood through the tube and subsequent hypotension.
      - Treatment is surgical.
- Infection of the skin or pleural space
  - Avoidable with strict attention to a sterile technique
    - Wound infection
    - Empyema
      - Higher in cases harboring a pleural effusion
      - Nosocomial colonization from respiratory tract
  - In traumatic cases, penetrating injury has a higher rate than blunt trauma
    - Direct entry of microorganisms
- Reexpansion pulmonary edema
  - Rare
  - 20% mortality rate
  - Reported in thoracentesis as well
  - Pathophysiology appears to be increased endothelial permeability and loss of integrity of the alveolar capillaries, leading to exudation of protein-rich fluid
    - Perhaps secondary to atelectasis, hypoxia, and a decrease in surfactant
  - May occasionally occur on the contralateral lung as well

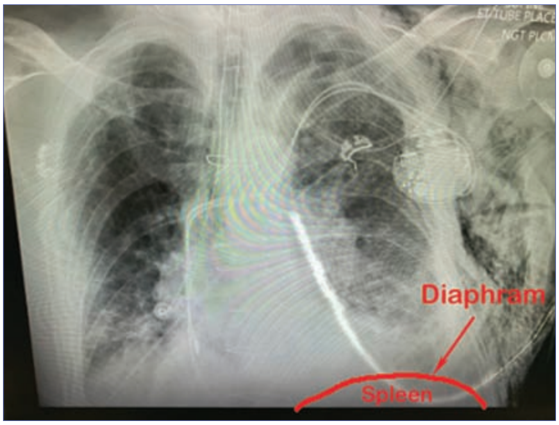


FIGURE 9.36 Left chest tube thoracostomy with a low entry point going through the spleen and diaphragm into the thoracic cavity. (Chest tube highlighted in white to show its course.) Also note the lateral chest wall subcutaneous emphysema.

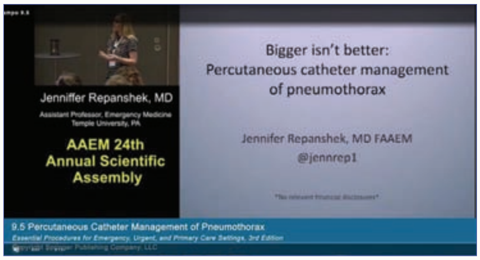
  - Risk factors
    - Young age (<40 years)
    - Collapse of the affected lung for more than 3 days
    - Large pneumothorax (>30% of single lung)
    - Application of significant negative pleural pressure suction and rapid lung reexpansion
  - Clinical picture varies from asymptomatic radiologic findings to dramatic respiratory failure with circulatory shock
  - Patient usually becomes symptomatic within 2 hours after rapid lung reexpansion
  - There may be frothy sputum production associated with tachypnea, tachycardia, and cyanosis
  - Auscultation may reveal rales, and chest radiograph will reveal the presence of pulmonary infiltrates with ground-glass appearance
  - Prophylactic measures include;
    - Recognizing patients at high risk
    - Low suction or simply an underwater seal
    - In cases of a thoracentesis (see Chapter 10, Pleural Effusion), ensuring that fluid exceeding 1 L must not be removed rapidly if the pleural pressure is not being monitored
    - Ideally, the goal should be to keep the pleural pressure above −20 cm H_2O
  - Diuretics should be avoided secondary to shock
  - Use positive end-expiratory pressure (PEEP), supplemental oxygen, mechanical ventilation if warranted, and vasopressor therapy if needed
- Residual/postextubation pneumothorax
  - Valsalva maneuver or exhaling upon catheter/tube removal decreases incidence
    - Small pneumothorax requires no therapy
  - Persistent air leak
    - Additional catheter/tube
    - Do not remove catheter/tube if air leak continues
- Chylothorax
  - Late complication secondary to a traumatic tube insertion and inadvertent injury to the thoracic duct

EDUCATIONAL POINTS

- The rate of recurrence of spontaneous pneumothorax:
  - Ipsilateral side—30%
  - Contralateral side—10%
- Other complications include:
  - Reexpansion pulmonary edema
  - Bronchopleural fistula occurs in 3% to 5%
  - Pneumomediastinum and pneumopericardium
- Persistent pneumothorax is defined as a continued air leak from a chest tube/catheter for more than 48 hours after insertion. Causes include:
  - Kink in tube/catheter
  - Catheter/tube malposition
  - Lung parenchymal disease
  - Bronchopleural fistula
  - Esophageal–pleural fistula
- SSP is associated with a higher morbidity and mortality than PSP.
- Strong emphasis should be placed on smoking cessation to minimize the risk of recurrence in both PSP and SSP.
- Observation is the treatment of choice for small PSP without respiratory distress.
- Up to 80% of pneumothoraces is estimated as smaller than 15%.
- Select asymptomatic patients with a large PSP may be managed by aspiration alone.
- Patients with a small PSP without respiratory distress can be considered for discharge with early outpatient revaluation; these patients should also receive clear written advice to return in the event of any respiratory symptomatology.
- Reexpansion pulmonary edema is a real complication and is lessened with the use of lower suction postcatheter/tube placement.
- Open thoracotomy and pleurectomy remain the procedures with the lowest recurrence rate at 1% for difficult or recurrent pneumothoraces.
- VATS with pleurodesis is better tolerated but has a higher recurrence rate of approximately 5%.

PEARLS

- Symptoms in PSP may be minimal or absent; in contrast, symptoms are greater in SSP, even if the pneumothorax is relatively small in size.
- The degree of respiratory distress influences the management strategy more than any other factor.
- Severe symptoms and signs of respiratory distress suggest the presence of tension pneumothorax.
- Pneumothorax is not usually associated with physical exertion.
- PSP can be safely discharged with or without treatment with early follow up; SSP should be treated and admitted.
- Pneumothorax does not mean an automatic chest tube; if treating one, think in a stepwise manner:
    - Observation
    - NA
    - Chest catheter
    - Chest tube (**VIDEO 9.6**)
- The increasing prevalence of vaping (21% of high school students vape as shown by Fadus, Smith, and Squeglia (2019)) is now another risk factor for pneumothorax (**FIGURE 9.37**).
    - Cannabis smoking has been associated with SP, too, and has been shown to have a greater burden of carbon monoxide and tar inhalation and accelerated formation of blebs compared to cigarettes; this has been attributed to greater puff-volume and depth of inhalation.
    - Smoking both tobacco and cannabis increases the risk for SSP even more.



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Bigger isn't better:

Percutaneous catheter management of pneumothorax

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9.5 Percutaneous Catheter Management of Pneumothorax

Essential Procedures for Emergency, Urgent, and Primary Care Settings, 3rd Edition

VIDEO 9.6 Bigger isn't better: Percutaneous catheter management of pneumothorax.

Source: Courtesy of Jenniffer Repanshek, MD, Temple University Department of Emergency Medicine.

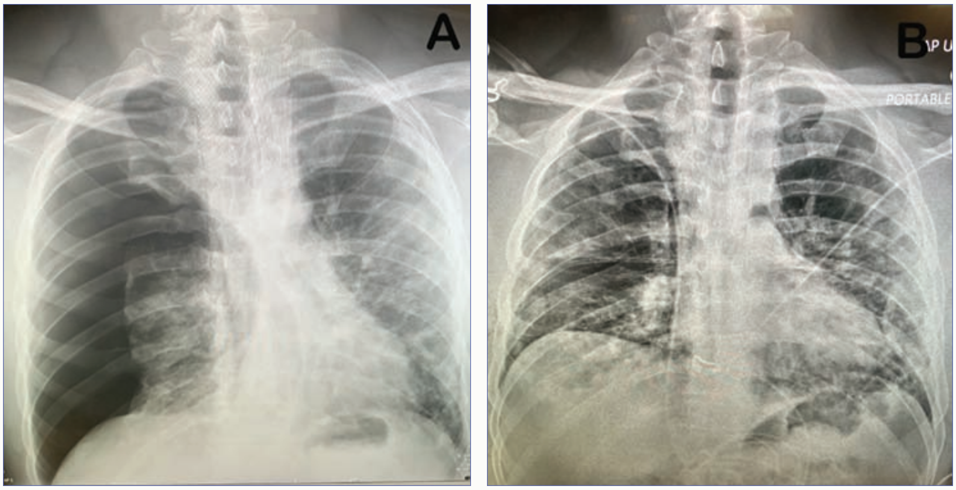

FIGURE 9.37 THC-vaping-induced tension pneumothorax. Note postchest catheter lung injury from the vaping-induced pneumonitis, which probably was a nidus for this SSP.

SSP, secondary spontaneous pneumothorax; THC, tetrahydrocannabinol.

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CHAPTER 10

Pleural Effusion

Amanda Bates, Megan Algeo, and Michael Farney

BACKGROUND

A pleural effusion is by definition the presence of fluid accumulation in the pleural space. When fluid accumulates in this space, it can lead to cough, chest pain, dyspnea, and ultimately respiratory and/or hemodynamic compromise. Effusions are categorized as either transudative or exudative based on their composition.

- A ***transudative effusion*** is caused by an imbalance between hydrostatic and oncotic pressures within the vasculature, leading to a collection of fluid in the pleural space with low protein content. In essence, it is caused by either an increase in intravascular hydrostatic pressure or a decrease in intravascular oncotic pressure. Causes of transudative effusions include the following:
  - Congestive heart failure (CHF; most common)
  - Cirrhosis
  - Nephrotic syndrome
  - Peritoneal dialysis
  - Pericardial disease
  - Myxedema
- An ***exudative effusion*** is typically the result of an inflammatory process leading to excessive pleural fluid secretion with a high protein content. Causes of exudative effusions include the following:
  - Infection (most common)
    - Bacterial
    - Viral
    - Mycobacterial
      - Tuberculosis (TB)
    - Malignancy
      - Obstructs the lymphatic outflow
  - Pulmonary embolism (PE)
  - Pancreatitis
  - Sarcoidosis
  - Chylothorax
  - Collagen vascular diseases
    - Rheumatoid arthritis
    - Systemic lupus erythematosus
  - Postmyocardial infarction
  - Esophageal perforation
    - Boerhaave's syndrome
  - Trauma
  - Aneurysm rupture/dissection
  - Radiation therapy

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

Anatomy

The pleural space is bounded by the parietal membrane (lining the chest wall) and visceral membrane (covering the lung parenchyma; **FIGURE 10.1**). Note the parietal pleura is innervated by the somatic nervous system, the intercostal nerves (the mediastinal and diaphragmatic pleurae are also innervated by the phrenic nerve). Because of this somatic innervation, pain is sharp. Visceral pleurae are innervated by the vagus nerve and sympathetic fibers and hence are insensitive to pain stimuli.

The space between these two linings is called the *pleural space* and is normally void of fluid except for a very small amount (<20 mLs) undetectable by imaging; this film of fluid helps lubricate the membranes to accommodate the dynamic and constant movements of the lungs. Similar to the pericardium, each pleural membrane consists of a superficial mesothelial cell layer and an underlying connective tissue layer containing leaky capillary beds that allow for easy movement of both fluid and protein. The pleural membranes and pleural space assist with the dynamic pressure changes of respiration. Pleural fluid is secreted by both the visceral and parietal layers, although it is drained only via the lymphatics in the parietal pleura via lymphatic stomas (**FIGURE 10.2**). Typically, 15 mLs of pleural fluid is made per day and, with normal homeostasis in place, net accumulation is zero. If the hydrostatic pressure is increased, as in transudative effusion, low-protein fluid is "pushed" into the pleural space via this hydrostatic pressure gradient. If the etiology is catabolic/inflammatory/destructive, the parietal membrane becomes more porous and a high-protein fluid accumulates in the pleural space.

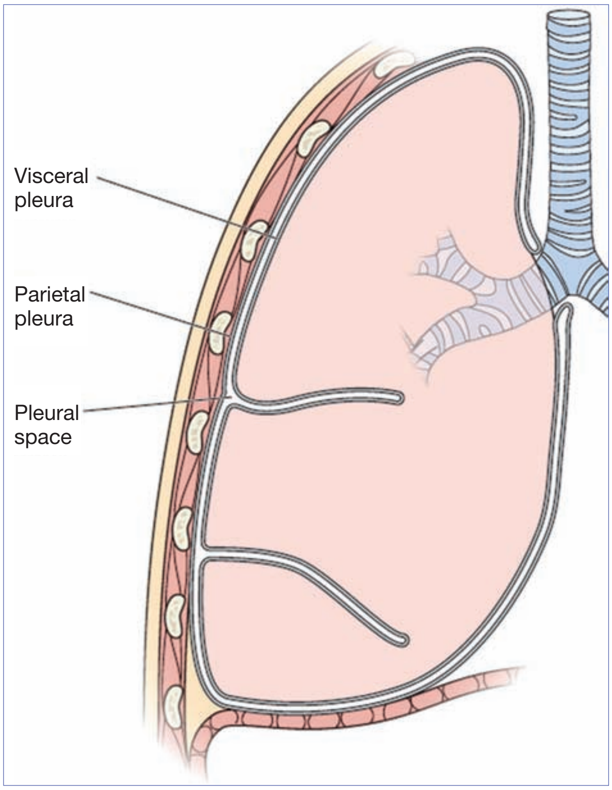


FIGURE 10.1 Visceral and parietal pleura membranes. Note the actual lung parenchyma (alveoli) are intimately covered by the visceral pleura; the parietal pleura is intimately in contact with the inner chest wall.

Source: Reproduced from Myrick, K. M., & Karosas, L. M. (2021). *Advanced health assessment and differential diagnosis: Essentials for practice*. New York, NY: Springer Publishing Company.

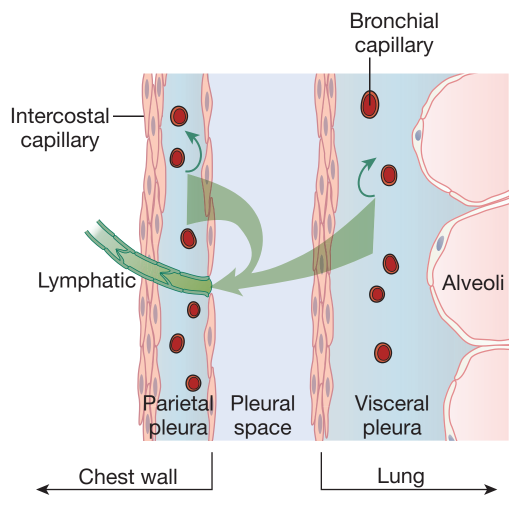


FIGURE 10.2 Pleural fluid production and drainage. Note these are dynamic and active tissues constantly creating a homeostasis of fluid creation and absorption.

Because fluid is denser than air, by virtue of gravity it accumulates in the most dependent area, the posterior costophrenic angle (**FIGURES 10.3**). This posterior recess can accommodate up to 250 mLs. Any further increase in fluid accumulation will next fill the lateral costophrenic angles. Because of this, be wary of ruling out a pleural effusion with a single posterior–anterior (PA) view chest x-ray (CXR); to visualize the posterior costophrenic angle one needs to see a lateral CXR. Likewise, when one notices "blunting" of the lateral costophrenic angles, there are already more than 250 mLs of pleural effusion.

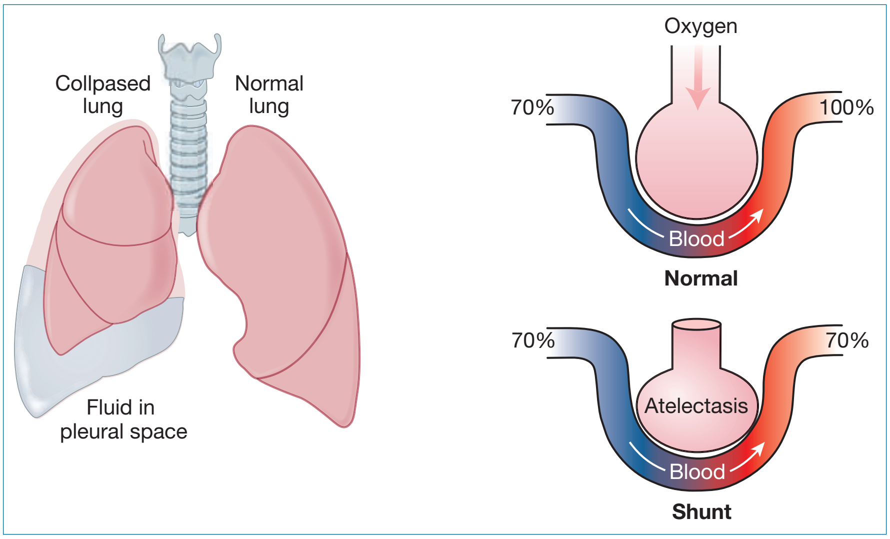


FIGURE 10.3 Pleural effusion. Note: Fluid collects in the most dependent areas and, as the effusion increases in volume, compressive atelectasis ensues, leading to the sequela of increased dead space ventilation. This is exacerbated in patients with compromised parenchyma to begin with, such as in chronic obstructive pulmonary disease (COPD), malignancies, pneumonia, and so on.

Diagnosis of a Pleural Effusion

- An effusion can be diagnosed with
  - Point of care ultrasound (POCUS)
    - Sensitivity approaches 100%
    - Can detect as little as 3 to 5 mLs of fluid
  - CT
    - Sensitivity is 100% and is considered the gold standard (**FIGURE 10.4** and **VIDEO 10.1**)
    - Patients must be stable

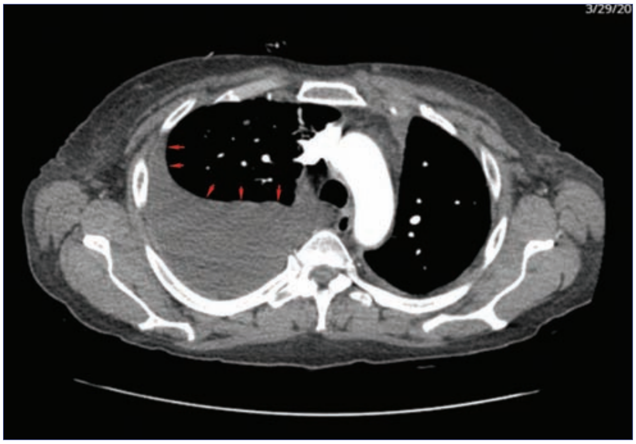
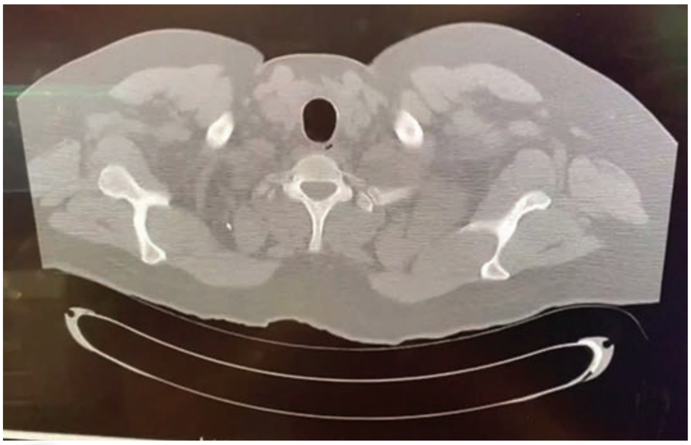


FIGURE 10.4 CT showing large right-sided pleural effusion.



VIDEO 10.1 Pleural effusion CT scan.

- CXR
  - Low sensitivity
  - Pleural effusion may be seen as blunting of the costophrenic angle with as little as 50 mL on a lateral upright film (**FIGURE 10.5**)
  - For an anteroposterior (AP) upright CXR, blunting of the costophrenic angle is often not visible until there is at least 200 to 250 mLs of fluid in the pleural space (**FIGURE 10.6**)

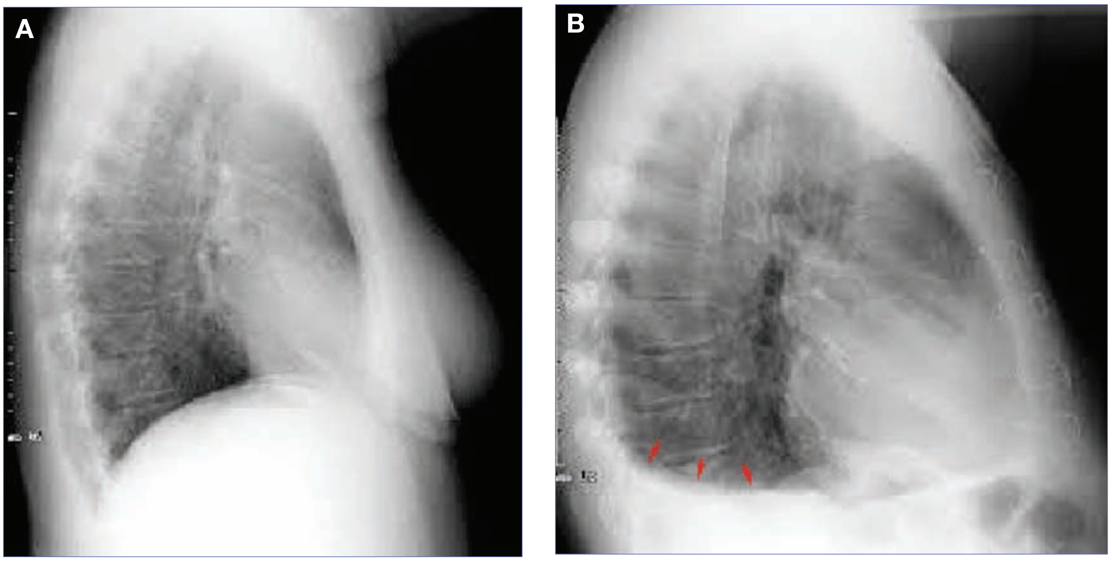


FIGURE 10.5 (A) Normal lateral CXR. (B) Lateral CXR showing pleural effusion; 50 mLs are needed in order for visualization to be possible. Note the deep posterior recess.

CXR, chest x-ray.

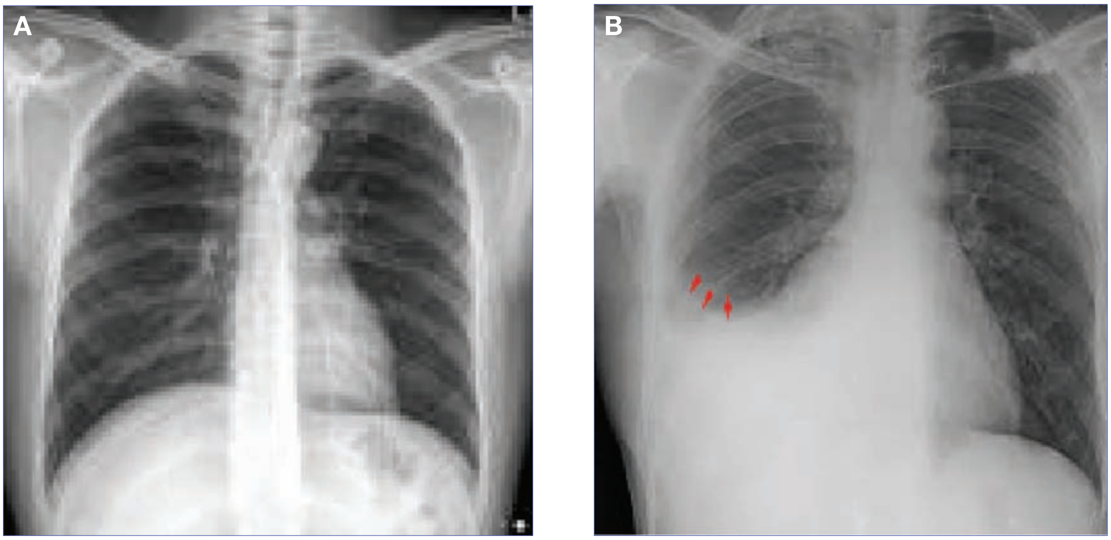


FIGURE 10.6 (A) Normal AP CXR. (B) AP CXR showing a right pleural effusion. Note at least 250 mLs are needed to start filling the lateral costophrenic angles; this is when the much deeper posterior recess gets full and fluid begins to move into the lateral recesses, allowing it to be visualized with this view.

AP, anteroposterior; CXR, chest x-ray.

- Larger effusions can show a “meniscus” sign on x-ray, meaning that the fluid creates a smooth slope with the outer edges higher than the center
- Massive effusions can cause a whiteout of the entire hemithorax
  - In these cases, shifting of the mediastinum away from opacification indicates an effusion (**TABLE 10.1**).

TABLE 10.1 **Minimum Amount of Fluid Required for Visualization of Effusion Based on Imaging Modality**

Imaging	Minimum Amount of Fluid Required for Visualization of Effusion (mL)	Sensitivity (%)	Specificity (%)
Ultrasound	5–20	92–100	93–100
CXR–lateral, upright	50	86	88
CXR–PA, upright	200–250	82	81
CXR–lateral decubitus	50	94	100

CXR, chest x-ray; PA, posteroanterior.

  - Physical exam
    - Lowest sensitivity
    - Studies have shown that the finding of dullness to percussion requires the presence of an effusion larger than 300 mLs
- POCUS is a preferred modality for identifying pleural effusion as it is:
  - Quick
  - Easy to perform at bedside
  - Does not expose the patient to radiation
  - Low cost
- Pleural effusions on ultrasound are identified as dark anechoic fluid above the bright white line of the diaphragm.
  - Consolidated lung may also be seen floating in the pleural fluid (**FIGURE 10.7**, **VIDEO 10.2**).
  - Loss of the usual mirror artifact of the liver above the diaphragm is often noted.
  - A “spine sign” can be visualized, which is when vertebral bodies are seen posteriorly due to the enhancing effect of fluid on ultrasound.
    - Versus normal lung in which the air artifact obscures the view

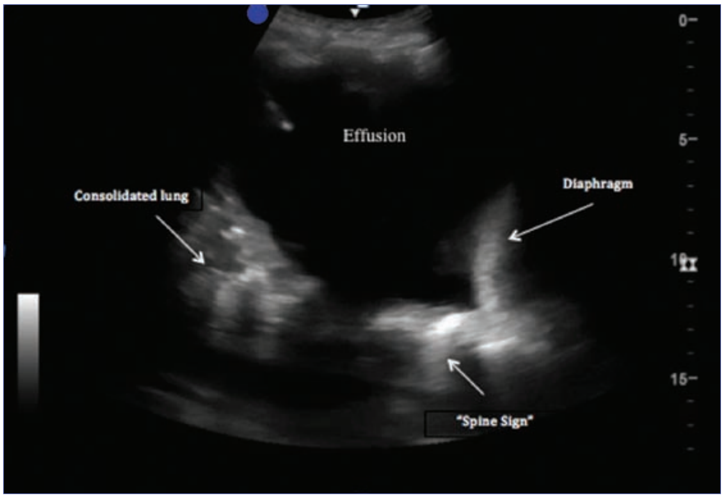
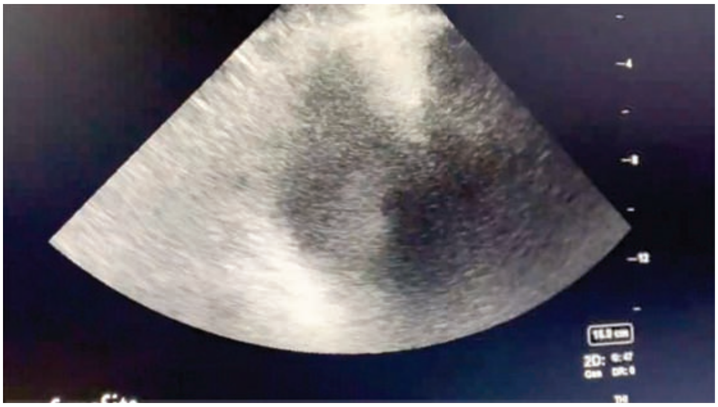


FIGURE 10.7 Ultrasound showing right-sided pleural effusion.

VIDEO 10.2 Pleural effusion ultrasound.



It is also useful to be able to further characterize the type of effusion with imaging prior to attempting an invasive procedure. Although transudative effusions generally remain free flowing, exudative effusions can become loculated due to inflammation, which leads to fibrinous adhesions. This is clinically important because these effusions may no longer be amenable to standard bedside thoracentesis or tube thoracostomy. In later stages of parapneumonic effusions, loculations may be visible on ultrasound. This further supports the use of ultrasound in the evaluation of pleural effusions. CT of the chest is the gold standard for the diagnosis and carries the highest sensitivity for detecting fluid and provides a more detailed view of the effusion, though again it exposes the patient to radiation and may not be a safe option for an unstable patient.

Be especially careful in ruling out a pleural effusion with a supine CXR. Large amounts of fluid can be present on *supine films* with a paucity of imaging changes. This is because the fluid is dependent and collects posteriorly; in many ways, the patient is lying on the fluid so there is no meniscus, and only a subtle increase in density in the ipsilateral hemithorax, which may be visible to the astute clinician. It is therefore especially difficult to identify similar-sized bilateral effusions as the density of the lungs will be similar.

PATIENT PRESENTATION

When effusions become large, they may lead to respiratory or hemodynamic compromise. This is due to compression of lung parenchyma (atelectasis and sequela of physiologic shunting) and a decrease in venous return. Patients may present with any of the following signs or symptoms:

- Cough
- Shortness of breath
- Chest pain
- Hypoxia
- Orthopnea
- Fever

Often patients' symptoms of pleural effusion are masked by symptoms of their primary medical condition, for example, malignancy, CHF, cirrhosis, infection, autoimmune disease, and so on. Some patients may even show no symptoms at all if fluid volume is small.

TREATMENT

Treatment of pleural effusions can be divided into two categories, either supportive care or removal of pleural fluid. This depends on suspected etiology of the effusion as well as patient condition. Thoracentesis is performed either to remove a small amount of fluid for laboratory testing to determine the cause of the effusion (diagnostic thoracentesis), or a larger amount in the case of large-volume pleural effusion leading to respiratory or hemodynamic compromise (therapeutic thoracentesis). In severe cases, thoracoscopy or thoracoscopic surgery may ultimately be required by a specialist to remove an empyema or effusions that have become loculated and are no longer amenable to drainage by thoracentesis or chest tube. Initial measures in the emergency setting should be directed at treating the underlying cause. If the effusion is thought to be infectious, the patient should be given antibiotics and resuscitated as appropriate. Effusions resulting from CHF typically respond well to diuretics. Supplemental oxygen or positive-pressure ventilation (either via noninvasive methods or intubation) may be indicated for patients suffering from respiratory compromise. In these cases, emergent therapeutic thoracentesis may also be indicated.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

For routine or elective outpatient thoracentesis, relative contraindications are:

- Coagulopathy
- Overlying cellulitis
- Overlying herpes zoster
- Heavily loculated effusions (unlikely to be able to adequately drain fluid with bedside thoracentesis)
- Coagulopathies (international normalized ratio [INR]>1.5)

For emergent thoracentesis, in cases of respiratory or hemodynamic compromise, there are no absolute contraindications. In all settings ultrasound guidance should be used to minimize the risk of complications.

PROCEDURE PREPARATION

- Positioning the patient properly is essential for safe and effective thoracentesis.
  - Ideally, the patient should be seated upright for a posterior approach.
  - With this technique the patient can lean over a small table, and an assistant can help stabilize the patient as they move forward (**FIGURE 10.8**).
  - In cases of emergent thoracentesis, when the patient may be unable to sit up due to severe respiratory or hemodynamic compromise, the procedure may be performed with the patient supine or in the lateral decubitus position.
- The British Thoracic Society (Havelock et al., 2010) describes a “triangle of safety” for thoracentesis as the area between the fifth intercostal space and base of axilla, bordered by the lateral edge of the pectoralis major anteriorly and the lateral edge of the latissimus dorsi posteriorly (**FIGURE 10.9**).
  - This area minimizes the risk of injury to internal organs, vascular structures such as the internal mammary artery, muscles, and breast tissue.
  - While the triangle of safety should be appreciated, and can be utilized, the editors of this book believe that secondary to the deep posterior pleural recess combined with the gravitational effects of fluid, the upright position, when able, is preferred; note, because air rises, this is in stark contrast to treating a pneumothorax (see Chapter 9).

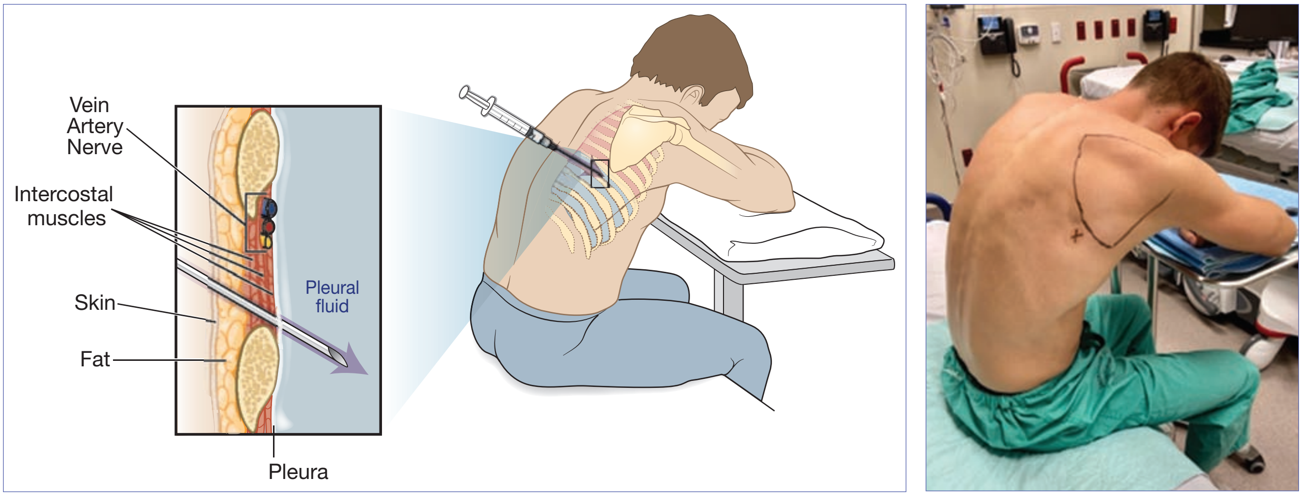
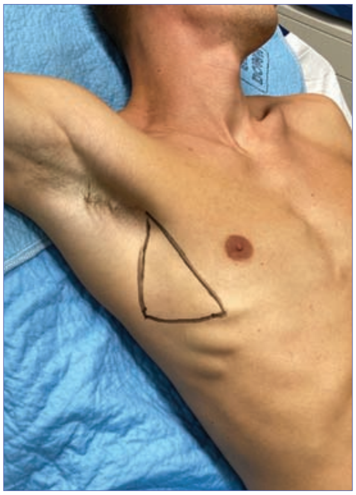


FIGURE 10.8 Patient position for thoracentesis. Inferior tip of scapula lies just superior to the seventh posterior rib. In general, do not attempt to go below this rib as inserting below the ninth rib increases the chances of inadvertently placing the needle below the diaphragm, causing a hemothorax.

FIGURE 10.9 Triangle of safety.



- Informed consent should be obtained in all routine settings coupled with the confirmation of patient identity, procedure, and side of the body ("time out") prior to beginning the procedure.
- Assemble all equipment needed prior to starting the procedure.
- Ultrasound guidance is recommended for thoracentesis to prevent damage to surrounding structures such as the lung, heart, diaphragm, liver, and spleen.
- The recommended use of ultrasound is through ***dynamic guidance*** with a sterile probe cover.
    - Note the superior level of the pleural effusion and, in general, attempt to place the needle in the intercostal spaces below this point; note that placing it in the largest area of fluid collection trumps the aforementioned, however.
    - During this procedure, the ultrasound can be used to visualize the needle tip as it travels through the skin and into the pleural effusion.
- As an alternative, ultrasound may be used beforehand for visualization and to mark the effusion and surrounding structures; this is referred to as ***static guidance.***
    - This is used once the patient is positioned, prior to the start of the procedure, if dynamic guidance is not possible.
- Many practice settings have commercially prepared thoracentesis kits available that include needles and catheters, as well as other necessary supplies, all packaged together.
- If a kit is unavailable, thoracentesis may be performed with readily available needles, tubing, and syringes as listed (**FIGURE 10.10**):
    - Small-gauge needle (ideally 20–22 g, use smaller needles for diagnostic thoracentesis)
    - Use of larger bore needles has been associated with pneumothorax
    - Connection tubing with three-way stopcock if using large canister for drainage
    - Syringes (ideally 30 mL or 60 mL for therapeutic procedures; use a smaller size if performing only diagnostic thoracentesis)

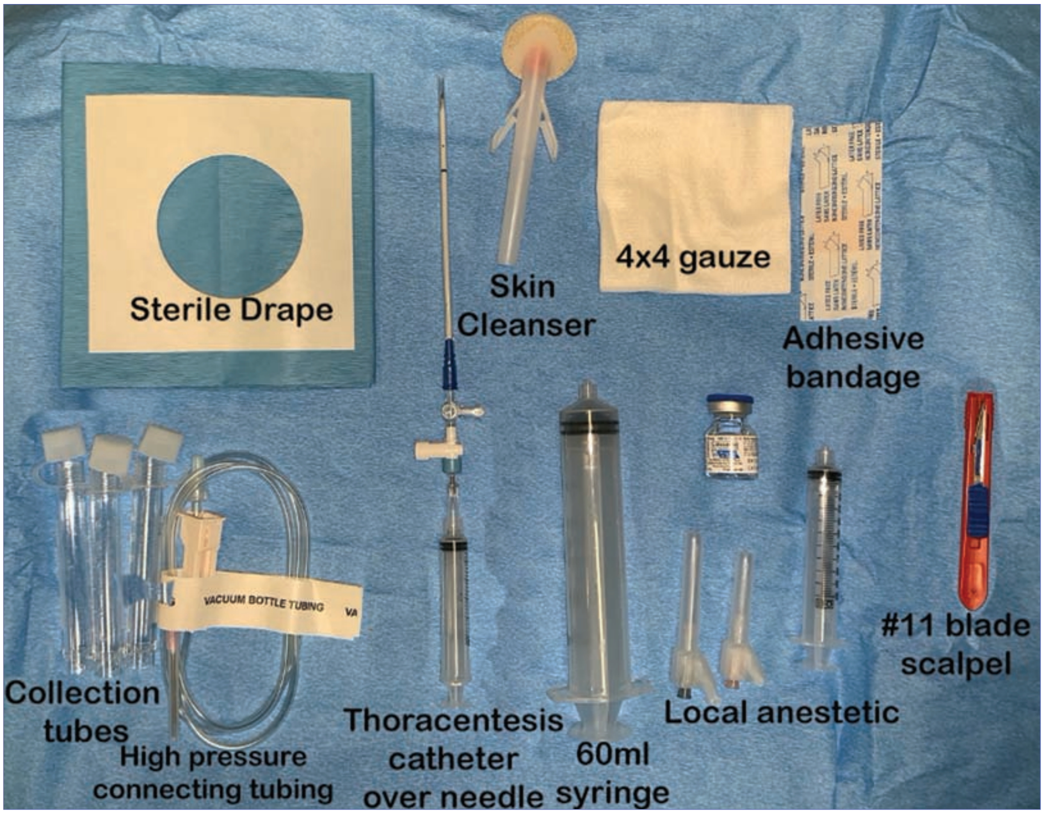

Sterile Drape
Skin Cleanser
4x4 gauze
Adhesive bandage
VACUUM BOTTLE TUBING
#11 blade scalpel
Collection tubes
High pressure connecting tubing
Thoracentesis catheter over needle
60ml syringe
Local anestetic

FIGURE 10.10 Thoracentesis equipment. Vacutainer bottles not shown.

  - Sterile container or vacuum bottle or bag for large-volume drainage
  - Chlorhexidine, povidone-iodine, or other appropriate skin cleanser
  - Lidocaine with syringe and 25-g needle
  - Sterile drape
  - Sterile probe cover for ultrasound
  - Sterile gloves, mask, cap, gown
  - Culture bottles if appropriate
  - Occlusive dressing

PROCEDURE

Initial steps for all techniques are as follows:

- Assemble all materials.
- Position patient appropriately.
  - Ideally sitting up and leaning forward over a padded table
  - Alternately, lying supine with the arm fully up and posteriorly with the bed elevated almost to a full upright position using the triangle of safety and greatest fluid pocket via ultrasound identification
  - If the patient cannot tolerate sitting up, the preferred position is the lateral decubitus with the hemithorax of target on the stretcher and the needle located posteriorly along the midscapular or posterior axillary line
- Follow standard precautions with use of gloves, mask, cap, and gown.
- If using ultrasound for static guidance, visualize and mark the height of the pleural fluid. Visualize and mark important surrounding structures as appropriate (i.e., height of diaphragm, etc. [**FIGURE 10.11**]).
  - Note that with respirations these structures will move.
  - Using the ruler gauge on the monitor, also note the depth from skin to pleural fluid during this step.
- Visualize the desired window for several respiratory cycles to ensure lung does not move into the anticipated puncture site.
- Use a skin cleanser, such as chlorhexidine, and apply sterile drape, probe cover.
- Ideally, using ultrasound guidance with sterile probe cover, identify the pocket of fluid between two rib spaces.
  - Note that it is recommended that the depth of the effusion be at least 10 mm.
  - Do not attempt thoracentesis without ultrasound guidance below the level of the ***eighth intercostal space***, as this significantly increases the risk of diaphragmatic, splenic, or hepatic injury.

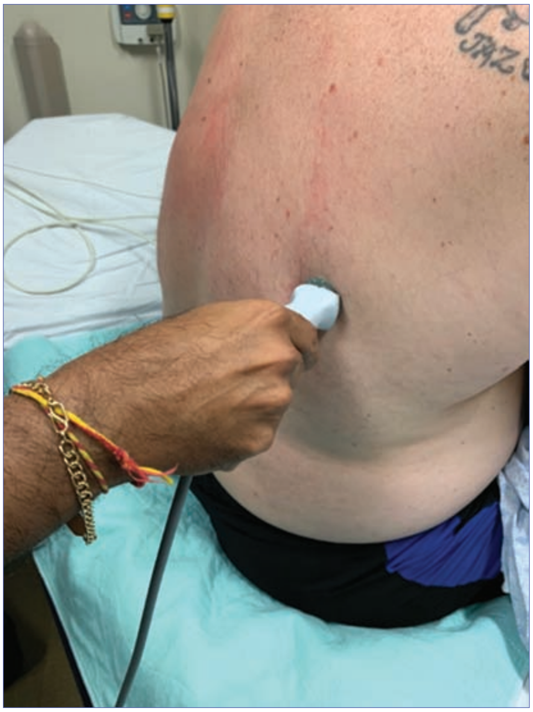


FIGURE 10.11 Patient and ultrasound probe position.

- Use a 25-g needle and syringe to anesthetize skin and superior aspect of rib with 5 to 10 mL of lidocaine; be sure to aspirate at each site prior to injecting anesthetic, continuing to aspirate and inject until you are in the pleural space and confirm the aspiration of pleural fluid (**FIGURE 10.12**).
  - This ensures both that the patient will be adequately anesthetized (parietal pleura has many sensory nerve fibers), and that you are properly positioned to access the effusion.
    - If no fluid is aspirated during this step, then stop the procedure and find an alternate location for thoracentesis.

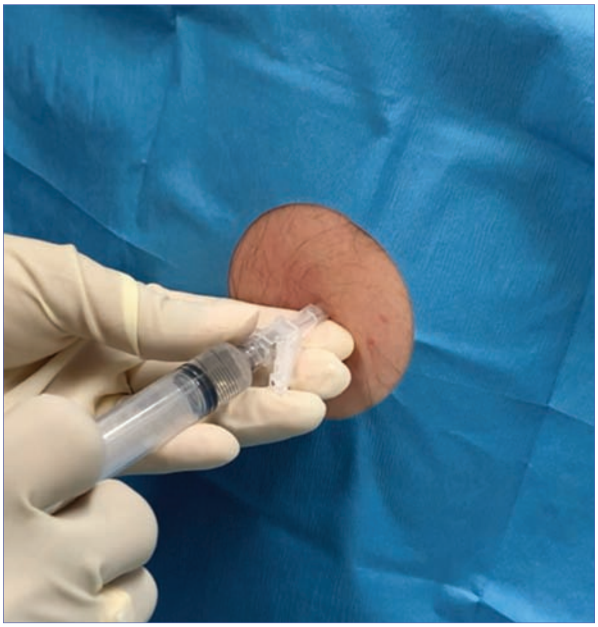


FIGURE 10.12 Local anesthesia injection while aspirating for pleural fluid.

Diagnostic or Small-Volume Thoracentesis

- Attach 20-g, or similar-sized needle, to a syringe and carefully direct it through the anesthetized skin and over the superior edge of the rib.
- Aspirate the entire time once the needle is through the skin.
- Stabilize the needle at the skin edge with two fingers and advance slowly/carefully until the needle is in the pleural space and there is return of pleural fluid in the syringe.
- Fill the syringe with fluid, carefully remove from skin, and apply occlusive dressing.

Large-Volume Thoracentesis Using a Standard Needle/Catheter

- Note: An ***assistant*** is needed for this procedure, as one person is required to hold the catheter steady at the skin edge while the other attaches/detaches the syringe or vacuum bottles.
- Attach 20-g, or similar-sized needle catheter, to a syringe.
  - Carefully direct the needle catheter through the anesthetized skin and over the superior edge of the rib, aspirating the entire time once the needle is through the skin.
  - Stabilize the needle catheter at the skin edge with two fingers of the nondominant hand, and advance slowly.
  - Do this until the needle catheter is in the pleural space and there is return of pleural fluid in the syringe.
  - Slide the catheter fully to the hub while withdrawing and removing the needle; the catheter hub should be resting with its hub against the skin; immediately attach the three-way stopcock in the off position.
- Turn the stopcock off so that no fluid leaks and no air can enter.
- There are two methods for draining fluid from this point:
  - Fluid from the syringe may be deposited into a container and the syringe may be attached to the stopcock.
    - As many times as desired, the stopcock can be turned back on and the syringe used to drain additional fluid that is deposited into the container.
    - Be sure that each time the syringe is removed, the stopcock is off so no air enters the pleural space.
  - Alternatively, tubing can be attached to the stopcock to connect it to a vacuum bottle or bag.
    - The stopcock can be turned on to allow fluid to drain directly into the bottle. Be sure to turn the stopcock off each time the bottle is changed.
- Once desired amount of fluid has been removed, carefully pull needle from skin and apply occlusive dressing.
  - The maximum recommended amount of fluid to be removed is 1,500 mL, to prevent complications of:
    - Reexpansion pulmonary edema
    - Hypovolemia

Large-Volume Thoracentesis Using a Thoracentesis Catheter

- Make small nick in anesthetized skin using a scalpel (**FIGURE 10.13**).
- Catheter should be loaded over introducer needle and the needle should be connected to a three-way stopcock and syringe (**FIGURE 10.14**).
- Carefully direct the needle and catheter through the anesthetized skin and over the superior edge of the rib, aspirating the entire time once the needle is through the skin.
    - Stabilize the needle at the skin edge with two fingers of the nondominant hand, and advance slowly/carefully (**FIGURE 10.15**).
    - Do this until the needle is in the pleural space and there is return of pleural fluid in the syringe.

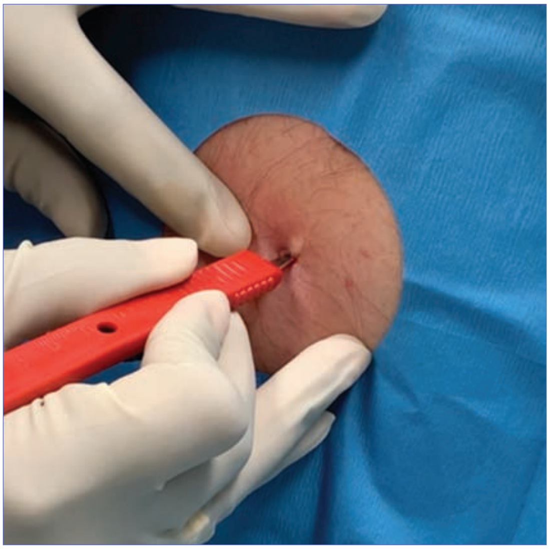


FIGURE 10.13 Small nick of skin with scalpel.

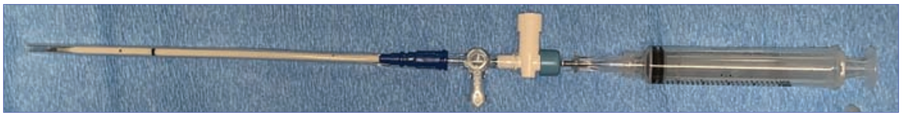


FIGURE 10.14 Typical thoracentesis done using a catheter-over-needle, three-way stopcock and syringe device.

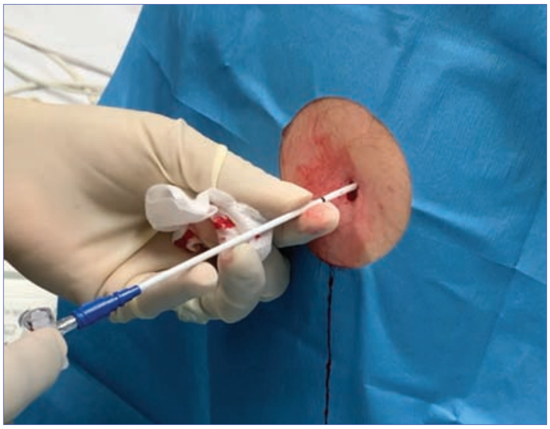


FIGURE 10.15 Insertion of thoracentesis needle catheter apparatus.

- Remove the needle from the catheter and turn the three-way stopcock to the off position at the end of the catheter. There are two methods for draining fluid from this point:
    - A syringe may be used to pull fluid from the catheter and then the syringe can be detached, and fluid deposited into a container.
        - The syringe may be reattached to the stopcock and the process repeated until enough fluid has been removed.
        - It is vital that the stopcock be turned off before the syringe is removed each time to prevent air from entering the pleural space (**FIGURE 10.16**).
    - As an alternative, additional tubing provided in the thoracentesis kit can be attached to the stopcock (lever off toward catheter) to connect it to a vacuum bottle or bag.
        - The stopcock can be turned on to allow fluid to drain directly into the bottle; be sure to turn the stopcock off each time the bottle is changed (**FIGURE 10.17**).
- Once the desired amount of fluid has been removed carefully, pull needle from skin and apply occlusive dressing. To prevent complications of hypovolemia or reexpansion pulmonary edema, the maximum recommended amount of fluid to be removed is 1,500 mL.
- This procedure can be visualized in **VIDEO 10.3**.

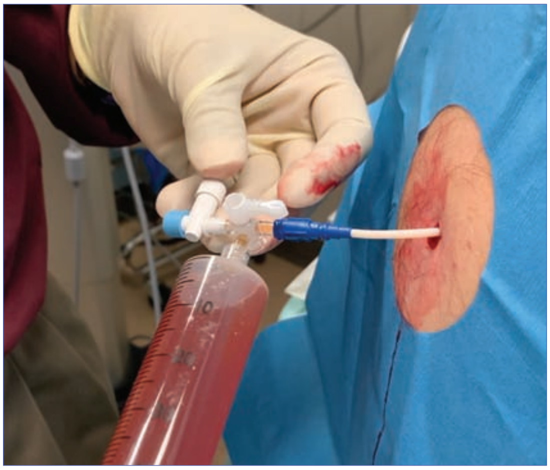


FIGURE 10.16 Syringe aspiration. Note the stopcock lever points to the off position. In this case after the syringe is full with pleural aspiration fluid, the lever is turned toward the catheter (off), allowing the syringe to empty its content and be reused for more aspiration fluid.

VIDEO 10.3
Thoracentesis using a formal kit.

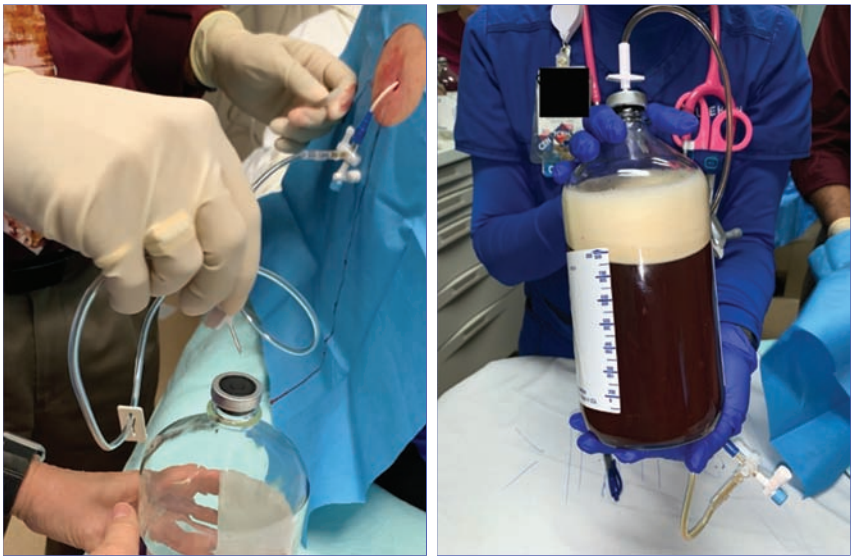


FIGURE 10.17 Vacutainer collection.

Troubleshooting

- Performing a thoracentesis and finding no fluid (dry tap) is a scenario that clinicians must be able to troubleshoot; reasons for a dry tap include:
  - Needle insertion is too high above the fluid level.
  - There is no fluid to begin with.
  - Patient moves during the procedure, therefore the fluid pocket within the pleura is no longer in line with the insertion point.
  - The equipment malfunctions, including use of too short a needle, kinked catheter, or a clogged needle.
  - Skin movement or skin indentation is misrepresented as pleural fluid during ultrasound evaluation.
  - If fluid stops flowing prematurely, this may be due to a condition called *pneumothorax ex vacuo*, which occurs when the lung tissue is not able to fully expand due to malignancy, prior infections, adhesions, or mucous plugs.
    - As fluid is draining, the output eventually halts because the negative pressure from the lung ceases any efflux of fluid.
    - Manometry can be used in this instance to measure intrapleural pressures and evaluate such a condition; further discussion of this topic is beyond the scope of this book.

POSTPROCEDURE CONSIDERATIONS

- Postprocedural pneumothorax has a historically wide range of reported incidence, anywhere from 2% to 30%.
- In a meta-analysis, Gordon et al. (2010) reviewed 24 studies for a total of 6,605 thoracenteses and found that the compiled risk of a postprocedural pneumothorax was 6% with one-third of these needing tube thoracostomy treatment.
  - However, the use of ultrasound guidance was associated with significantly lower risk of pneumothorax (OR, 0.3).
- Mercaldi and Lanes (2013) conducted an observational cohort study examining the effect of ultrasound guidance on risk of pneumothorax among patients undergoing thoracentesis; they analyzed 61,261 thoracenteses cases and found that a pneumothorax occurred in 2.7%.
  - Ultrasound guidance reduced the risk of pneumothorax after thoracentesis by 19%.
- Cho et al. (2017) reviewed 3,067 emergent thoracentesis cases and found the rate of an iatrogenic pneumothorax to be 0.62%.
- Patients should be monitored for signs and symptoms of pneumothorax, including worsening tachypnea, hypoxia, chest pain, and hypotension.
- Although postprocedure CXR may not be required in uncomplicated cases, the clinician should obtain one in the following scenarios:
  - Patient instability
  - Mechanical ventilation
  - Technically difficult procedures
    - Multiple needle passes
    - Challenging anatomy
    - POCUS images cannot be saved
- ***At a minimum, after the procedure perform POCUS for lung sliding.***

Respiratory status and hemodynamics should be monitored, particularly after large-volume thoracentesis, for the rare but serious complications of reexpansion pulmonary edema and hypovolemia. Most experts list a maximal volume for removal as 1.5 L, though the risk of removing greater volume is low. In one recent study of patients undergoing thoracentesis, 87 out of 185 had greater than 1.5 L removed and only one of those patients had clinical signs of reexpansion pulmonary edema.

Analysis of Pleural Fluid

- Once pleural fluid is collected, it should be sent for diagnostic testing.
- The first and most important step is to evaluate whether the fluid is exudative or transudative.
- One such test to distinguish the two is called *Light's criteria*, which is highly sensitive for detecting exudative pleural fluid.

- Light's criteria distinguishes transudative from exudative effusions based on serum and fluid studies (**BOX 10.1**).
- The three-test rule is another test that can be used to help distinguish between transudate and exudate (**BOX 10.2**).
    - This test has the advantage of not needing to obtain a serum sample.
- Once the diagnosis of exudate versus transudate has been made, fluid samples can be sent for further analysis.
- Cell count, culture, cytology, cholesterol, glucose, pH, amylase, and other levels can help narrow proposed differential diagnoses.

BOX 10.1 Light's Criteria

The effusion is considered *exudative* if it meets any one of the following criteria:

- Pleural fluid/serum protein ratio >0.5
- Pleural fluid/serum lactate dehydrogenase (LDH) ratio >0.6
- Pleural fluid LDH is greater than two-thirds of the upper limit of normal for serum LDH

BOX 10.2 Three-Test Rule

The effusion is considered *exudative* if it meets any one of the following criteria:

- Pleural fluid protein greater than 2.9 g/dL (29 g/L)
- Pleural fluid cholesterol greater than 45 mg/dL (1.165 mmol/L)
- Pleural fluid LDH greater than 0.45 times the upper limit of the lab's normal serum LDH

EDUCATIONAL POINTS

- Pleural effusions can be caused by numerous processes, including infection, malignancy, CHF, autoimmune disease, iatrogenic, hepatic or renal failure.
- Ultrasound is a safe and accurate way to diagnose a pleural effusion at the bedside.
- Thoracentesis can be performed for diagnostic or therapeutic purposes.
- Almost 20% of PEs develop a pleural effusion; the astute clinician should remember this occurs in patients with otherwise unexplained dyspnea.
- Abnormal cells from cytology indicate a malignancy as the etiology.
- Ultrasonography allows characterization of pleural fluid collections with septations and loculations being better appreciated than on CT scan, but pleural thickening, the extent of pleural disease throughout the thorax, and lung parenchyma are more easily appreciated on CT imaging.
- CT scan cannot visualize normal pleurae against the chest wall because pleural membranes blend in with endothoracic facia and intercostal muscles.
- Conditions that thicken the pleurae render them visible on CT scan; parietal pleural thickening almost always indicates the presence of a pleural exudate, although this finding is not specific for an infectious etiology.
- Expert opinion advises that demonstration of loculations and pleural thickening by CT scan or ultrasonography identifies patients with later stage empyema who will likely fail chest-tube drainage and require surgical management.
- The American College of Chest Physicians clinical practice guideline for empyema management recommends initial imaging findings for guiding therapeutic decisions; predictors of a poor prognosis with typical thoracentesis technique and who would be better treated initially with surgical drainage include the following:
    - Pleural effusions that occupy greater than 50% of the hemithorax
    - Presence of pleural loculations
    - Signs of pleural thickening (CT)

COMPLICATIONS

- Complications can be minimized by using ultrasound to guide the procedure.
- Inexperienced clinicians, challenging anatomy, larger/longer needles, or poor technique can still lead to complications such as:
  - Pneumothorax
    - Ultrasound decreases this risk significantly.
      - Higher in patients with:
        - ❑ Larger/longer needles
        - ❑ Multiple attempts
        - ❑ An abnormally low body mass index (BMI)
        - ❑ Not using ultrasound guidance
          - ❑ Without the use of POCUS, the clinician may inadvertently place the needle too high and above the pleural effusion and in so doing penetrate the visceral pleura.
  - Infection
  - Hemothorax
  - Reexpansion pulmonary edema with large-volume removal
  - Inadvertent needle placement in the spleen/liver
  - Hypotension
    - Large amounts of fluid removed

PEARLS

- Effusions are generally divided into transudative or exudative effusions based on composition, specifically protein levels.
- Thoracentesis can be diagnostic or therapeutic.
- Ultrasound guidance is recommended to minimize complications.
- A total of 1,500 mL is the maximum recommended amount of fluid to remove in a single session.
- Almost 90% of pleural effusions are caused by CHF, pneumonia, PE, malignancy, and gastrointestinal (GI) diseases.
- Although the diagnosis depends upon the fluid analysis, there are certain hints that one can guesstimate by visual inspection of the pleural effusion:
  - Bloody (**FIGURE 10.18**)
    - Trauma
    - Malignancy
    - PE
    - Pneumonia
  - Milky
    - Lipids
  - Purulent/malodorous
    - Empyema
  - Food
    - Esophageal rupture
- How much is too much? (When should one cease the thoracentesis?)
  - Literature not clear though most experts state:
    - 1,500 mLs is the maximum amount to withdraw:
      - Reexpansion pulmonary edema can occur as a result of the intra pleural pressures becoming more negative than 20 cm H_2O.
      - Typically not measured in the ED upon thoracentesis.
      - Limiting the tap to 1,500 mLs of fluid may safeguard against this phenomenon.
    - Cough reflex
      - May signify the thoracentesis catheter is making contact with the visceral pleura; can cause a pneumothorax if the viscera is violated.

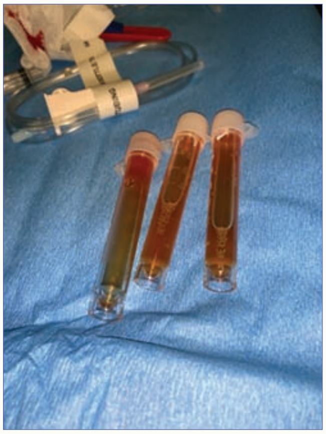


FIGURE 10.18 Blood-tinged pleural effusion.

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CHAPTER 11

Pericardial Effusion

Ryan C. Gibbons

BACKGROUND

Medical practitioners have been utilizing focused cardiac ultrasound (FOCUS) for nearly 30 years. Although similar in practice and theory, FOCUS differs from comprehensive echocardiography. As with most point-of-care ultrasound applications, focused transthoracic cardiac ultrasound is a goal-directed assessment of a symptomatic patient employed to answer specific clinical questions and serves as an adjunct to the physical exam. It is a rapid, safe, and effective means to not only diagnosis numerous cardiac pathologies but expedite treatment as well.

TABLE 11.1 illustrates many of the basic and advanced applications of cardiac ultrasound. This discussion focuses solely on pericardial effusions. Echocardiography remains the diagnostic study of choice for the detection and evaluation of pericardial effusions. In fact, as of 2003 the American Heart Association (AHA), American College of Cardiology (ACC), American Society of Echocardiography (ASE) have a level-1 recommendation for the use of echocardiography in the evaluation of all pericardial disease. It not only provides qualitative and quantitative information but enables assessment of the patient's hemodynamic status and guides treatment as well.

The pericardium is a hyperechoic sac that surrounds the heart and great vessels and consists of an outer fibrous parietal layer and inner serous visceral layer also known as the *epicardium*. Normally, a small amount of physiologic fluid (5–50 mL) surrounds the heart in order to provide lubrication during heart beating, cushion the organ, and protect against infection. The pericardium's visceral cells, which line the membrane, may also have a role in the absorption of the pericardial fluid along with the pericardial lymphatics. Its chemical makeup is similar to the cerebrospinal fluid (CSF) bathing the brain and spinal cord in the subarachnoid space.

TABLE 11.1 Roles of FOCUS

Basic (The Five E's of Echo)	Advanced
Entrance (IVC) Exit (Aortic outflow tract) ■ Aortic dissection or thoracic aortic aneurysm Equality (RV:LV)* Ejection fraction Effusion	Valvular pathology Cardiac arrest Volume assessment Diastolic dysfunction HOCM Ischemia (RWMA) Thrombus & mass identification eFAST (trauma) Undifferentiated ■ Chest pain ■ Dyspnea ■ Hypotension (RUSH protocol) Procedural ■ Pericardiocentesis ■ Transvenous pacer placement

*Typical size ratio RV:LV is 0.6:1.0;

eFAST, extended focused assessment with sonography for trauma; FOCUS, focused cardiac ultrasound; HOCM, hypertrophic cardiomyopathy; IVC, inferior vena cava; LV, left ventricle; RUSH, rapid ultrasound for shock and hypotension; RV, right ventricle; RWMA, regional wall motion abnormalities.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

With uncomplicated pericardial effusions, excess fluid initially accumulates in the most dependent areas, typically posteriorly and inferiorly around the right atrium, which is normally the chamber with the lowest pressure. Effusions rarely accumulate only anteriorly without a history of prior scarring or cardiac surgery.

Pericardial effusions fall on a spectrum from asymptomatic to severe hemodynamic compromise. Effusions develop gradually or acutely depending on the clinical scenario. Etiologies are numerous as are their classifications. **TABLES 11.2** and **11.3** provide a brief overview.

TABLE 11.2 Pericardial Effusion Classifications

Size (mm)*	Composition	Onset (weeks)	Distribution**	Definition
<10 small	Transudative	<1 acute	Circumferential	Simple
10–20 moderate	Exudative	<12 subacute	Focal	Complex
>20 large		>12 chronic		

*Measured at end-diastole using visual estimation or M-mode. Trace or physiologic <50 mL is within normal limits. Others define effusion size as follows (in mm): <10, 10 to 15, >15.

**Utilize multiple cardiac views to assess for focal effusions.

TABLE 11.3 Causes of Pericardial Effusion

Common	Less Common
Autoimmune disorders Neoplasm[*] ■ Lung ■ Breast ■ Leukemia ■ Lymphoma ■ Melanoma Idiopathic cause ■ 20% to 86%, most thought to be viral Infectious disease ■ >60% tuberculosis worldwide ⇨ Often with HIV Iatrogenic[*] illness Metabolic disorders ■ Hypothyroidism, uremia	Trauma Myocardial infarction Aortic dissection Coagulopathy Radiation Congestive heart failure Valvular heart disease Myopericardial disease Systemic illness ■ Cirrhosis ■ Nephrotic syndrome Medications ■ Antineoplastic medications ■ Medications that cause lupus-like syndrome[**]

*Most likely to need a pericardiocentesis.

**Procainamide, hydralazine, methyldopa, isoniazid, and phenytoin.

Indications

TABLES 11.4 to **11.6** review the risk factors, signs and symptoms, and classic EKG and chest x-ray findings that may warrant a FOCUS to assess for a pericardial effusion or other cardiac pathology (**FIGURES 11.1–11.4**).

TABLE 11.4 Risk Factors for Pericardial Effusions

■ ≥50 years old	■ Thyroid disorder
■ Male	■ Hypertension
■ Pericarditis	■ Smoking
■ Trauma	■ Family history
■ Malignancy	■ Coronary artery disease
■ Rheumatologic disorders	■ Diabetes mellitus
■ Congestive heart failure	■ Hyperlipidemia
■ Renal disease	■ Peripheral artery disease

TABLE 11.5 Signs and Symptoms of Pericardial Effusions

Symptoms	Signs
■ Undifferentiated ⇨ Chest pain ⇨ Positional; relief when sitting forward ⇨ With pericarditis ⇨ Back pain ⇨ Flank pain ⇨ Abdominal pain ■ Undifferentiated ⇨ Dyspnea <13% with effusion ⇨ Orthopnea ⇨ PND ■ Nonspecific/constitutional ⇨ Nausea ⇨ Dysphagia ⇨ Anorexia ⇨ Fatigue	■ PEA arrest ■ Beck's triad ⇨ Jugular venous distention ⇨ Distant, muffled heart sounds ⇨ Hypotension ■ Pulsus paradoxus ■ Pericardial friction rub ■ Edema ■ Hepatojugular reflex ■ Kussmaul's sign* ■ Syncope ■ Cyanosis ■ Abnormal VS ⇨ Shock/hypotension** ⇨ Tachycardia ⇨ Tachypnea ■ Thromboembolic events to the extremities*** ⇨ Weak or absent pulses ■ Neurologic deficit of the extremities*** ■ CVA and/or carotid dissection*** ■ Nonspecific: Cough, fever, hiccups

*Paradoxical venous distention with inspiration (JVD).

**Undifferentiated shock/hypotension (RUSH protocol); patients with chronic hypertension may not exhibit hypotension.

***Possible aortic dissection (pericardial effusion may be the only visible sign of an AoD on FOCUS) or AAA.

AAA, abdominal aortic aneurysm; AoD, aortic dissection; CVA, cerebrovascular accident; FOCUS, focused cardiac ultrasound; PEA, pulseless electrical activity; PND, paroxysmal nocturnal dyspnea; RUSH, rapid ultrasound for shock; VS, vital sign.

TABLE 11.6 Classic EKG and Chest X-ray Findings

EKG	Chest X-ray
■ Effusion: Low voltage (**FIGURE 11.1**) ⇨ Nonspecific: Seen in obesity and hyperinflation ■ Pericarditis (**FIGURE 11.2**) ⇨ Diffuse ST elevations (concave up) ⇨ Diffuse PR depressions ⇨ No reciprocal changes ⇨ TP segment down-sloping (Spodick sign) ■ Tamponade (**see VIDEOS 11.11–11.14**) ⇨ Electrical alternans (**see FIGURE 11.3** & **VIDEOS 11.10 11.11**) ⇨ Beat to beat variation of P, QRS, T-wave amplitudes ⇨ Pathognomonic for chronic pericardial effusion ⇨ Highly specific	■ Cardiomegaly ■ Enlarged cardiac silhouette ⇨ Water bottle sign (**FIGURE 11.4**) ⇨ >200 to 300 mL minimum ⇨ FOCUS detects as little as 15 to 35 mL

FOCUS, focused cardiac ultrasound.

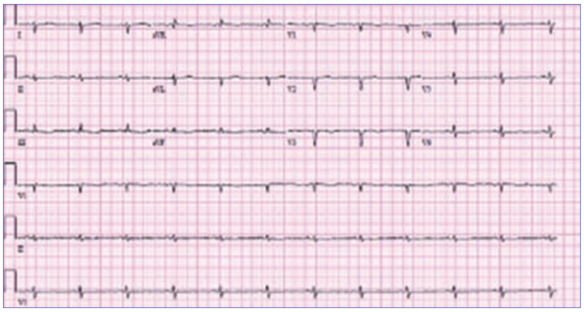

FIGURE 11.1 Low voltage.

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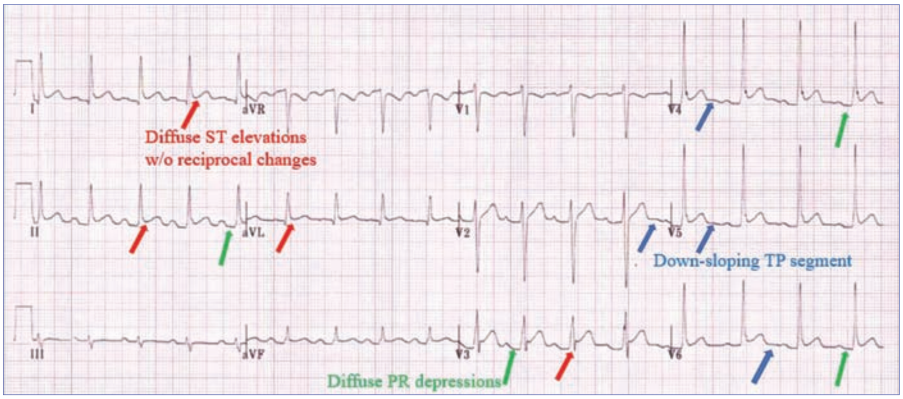

FIGURE 11.2 EKG findings of pericarditis.

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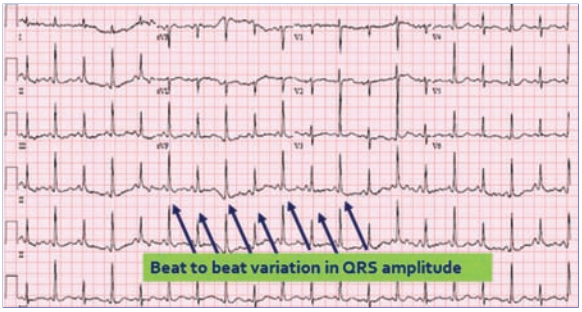

FIGURE 11.3 Electrical alternans.

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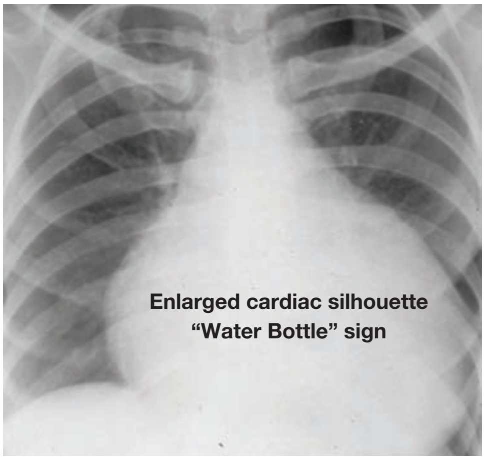

FIGURE 11.4 Enlarged cardiac silhouette showing “water bottle sign.” Note that one should not describe as an enlarged heart (cardiomegaly) on a chest x-ray due to the possibility that the enlargement is a sequala of a pericardial effusion and not the former.

Source: Reproduced with permission from Gibbons, R. (n.d.). *Pericardial effusion.* Retrieved from https://www.saem.org/cdem/education/online-education/m3-curriculum/bedside-ultrasonagraphy/pericardial-effusion

Stolz et al. (2017) retrospectively reviewed 150 patients with pericardial effusions/tamponade diagnosed in the ED setting via FOCUS; they found the most common chief complaint was dyspnea (63%) followed by chest pain (42%). The sensitivity of Beck’s triad was low (0–19%) and concluded that a low threshold should be maintained for performing FOCUS as historical physical examination signs are unreliable.

Preparation

As with any ultrasound study, proper setup is key to obtaining accurate images. The patient should be placed in the supine position at the level of the scanner’s waist with the head of the bed slightly raised to 30°. Dim the lights as appropriate and apply adequate ultrasound gel, especially with the subcostal view, to maintain suitable contact between the probe and skin.

Utilize the cardiac presets when scanning the heart. Modify the gain, frequency, and depth to refine your images. The initial depth should be maximized in order to display the entire heart, including the posterior pericardium. Adequate depth is particularly important with the subxiphoid window. Once the entire heart is visualized, the depth can be adjusted accordingly to optimize your view.

Have the patient lie in the left lateral decubitus position to enhance imaging, especially for the apical four chamber (A4Ch). Nonetheless, up to 25% to 30% of patients will not have an adequate A4Ch window. Advanced imaging, such as transesophageal echocardiography (TEE), CT, or cardiac MRI, is then required based on the clinical indication and the patient's hemodynamic stability.

Technique

Imaging of the heart is done in real time. The 1 to 5 mHz phased array (cardiac) probe (**FIGURE 11.5**) is utilized routinely given its small footprint, which augments intercostal imaging. Hold the probe similar to a pencil, resting your hypothenar eminence on the chest wall, which allows better manipulation of the probe. Typically, there are four standard cardiac views (**FIGURES 11.6** and **11.7**): parasternal long axis (PSLA or PLAX), parasternal short axis, (PSSA or PSAX), A4Ch, and subcostal or subxiphoid. There are additional advanced views and applications that are beyond the scope of this review.

To begin, place the probe along the left parasternal border in the 2nd through 5th intercostal space. Traditionally, the probe indicator *(circled in* **FIGURE 11.5***)* is oriented to the patient's right shoulder to obtain the PSLA view (**FIGURE 11.8** and **VIDEOS 11.1** and **11.2**). Rotate the probe 90° clockwise to acquire the PSSA image (**FIGURE 11.9** and **VIDEOS 11.3** and **11.4**). Maintain the indicator's alignment toward the left shoulder or axilla while sliding in the direction of the cardiac apex or PMI (point of maximum impulse) to visualize the A4Ch, which is typically along the left lateral chest wall in the 5th intercostal space inferolateral to the nipple (**FIGURE 11.10** and **VIDEOS 11.5** and **11.6**). Have female patients lift their breasts to improve imaging. Flatten your angle to optimize your A4Ch view. You may need to position your hand over the probe to achieve the appropriate angle. Place the patient in the left lateral decubitus position to augment the A4Ch view as well.

The subcostal view is typically the easiest and most reliable at detecting pericardial effusions because the most dependent portion of the heart is nearest to your probe. In addition, it is often the best view to distinguish between pleural and pericardial effusions as there is no pleural reflection between the liver and

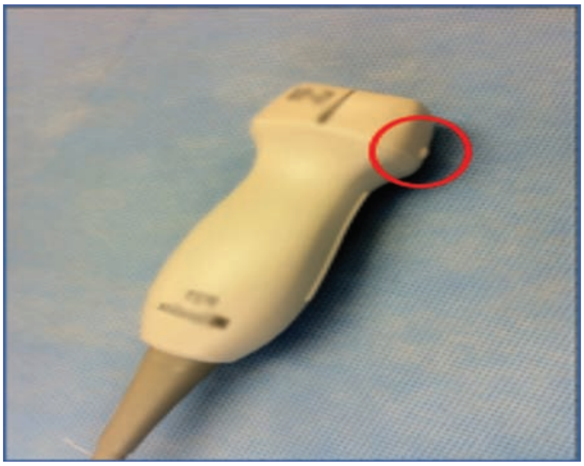

FIGURE 11.5 Phased array (cardiac) probe.

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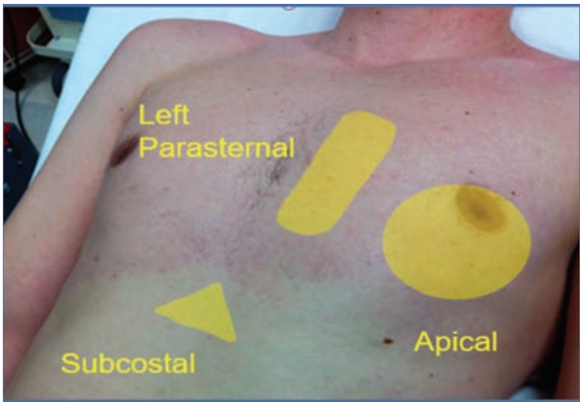

FIGURE 11.6 Standard cardiac windows and indications.

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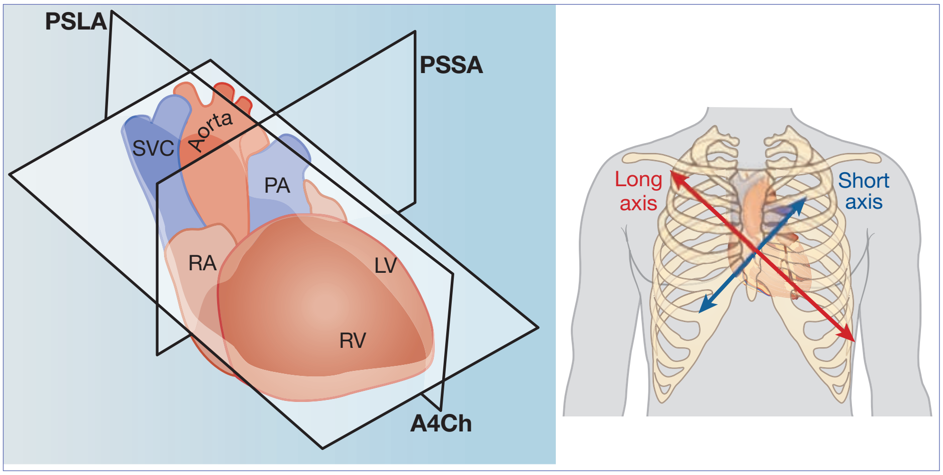


FIGURE 11.7 Standard cardiac axes.

A4Ch, apical four chamber; LAX, long axis; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SAX, short axis; SVC, superior vena cava.

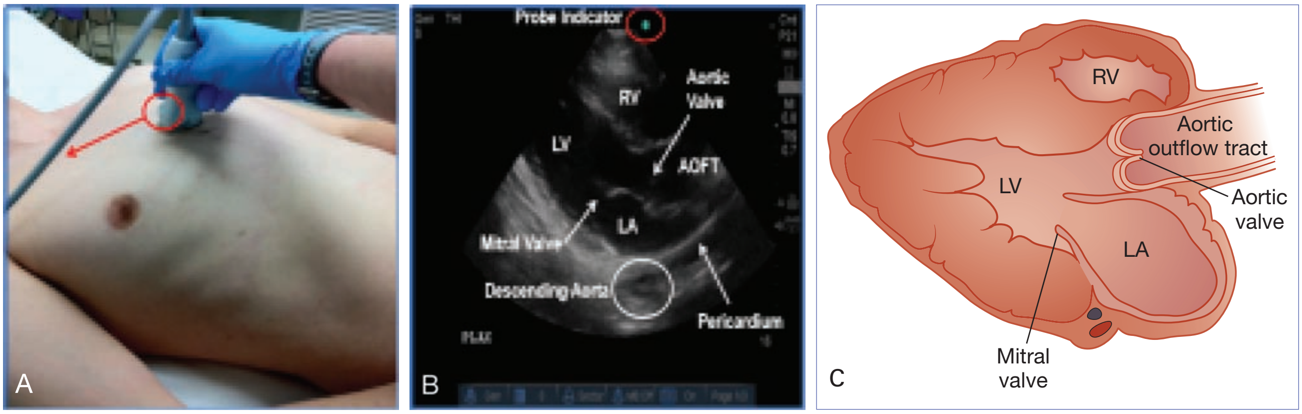
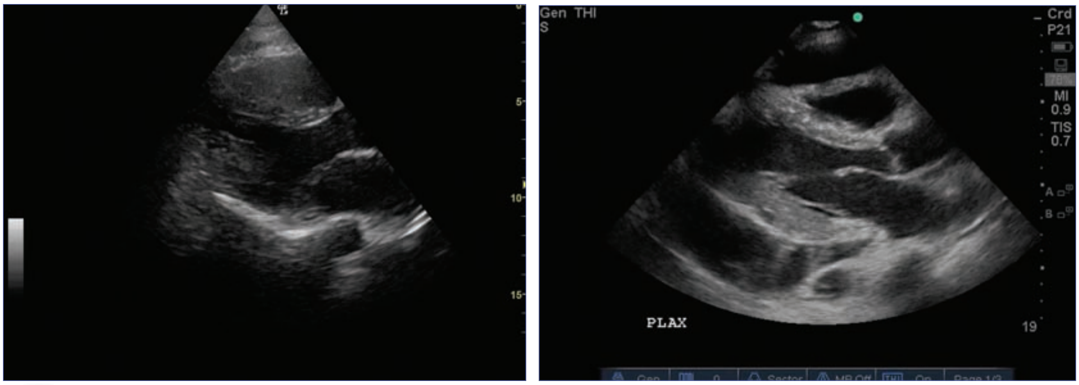

A
Probe Indicator
RV
Aortic Valve
LV
AOFT
Mitral Valve
LA
Descending Aorta
Pericardium
PLAX
B
RV
Aortic outflow tract
LV
Aortic valve
LA
Mitral valve
C

FIGURE 11.8 PSLA view.

Sources: (A) Reproduced with permission from Gibbons, R. (n.d.). *Pericardial effusion.* Retrieved from https://www.saem.org/cdem/education/online-education/m3-curriculum/bedside-ultrasonagraphy/pericardial-effusion; (B) courtesy of Thomas Costantino

AOFT, aortic outflow tract; LA, left atrium; LV, left ventricle; RV, right ventricle.


5
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S
Crd
P21
MI
0.9
TIS
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PLAX
19

VIDEOS 11.1 AND 11.2 PSLA normal and PSLA with effusion.
PLAX/PSLA, parasternal long axis.
Source: Courtesy of Thomas Costantino.

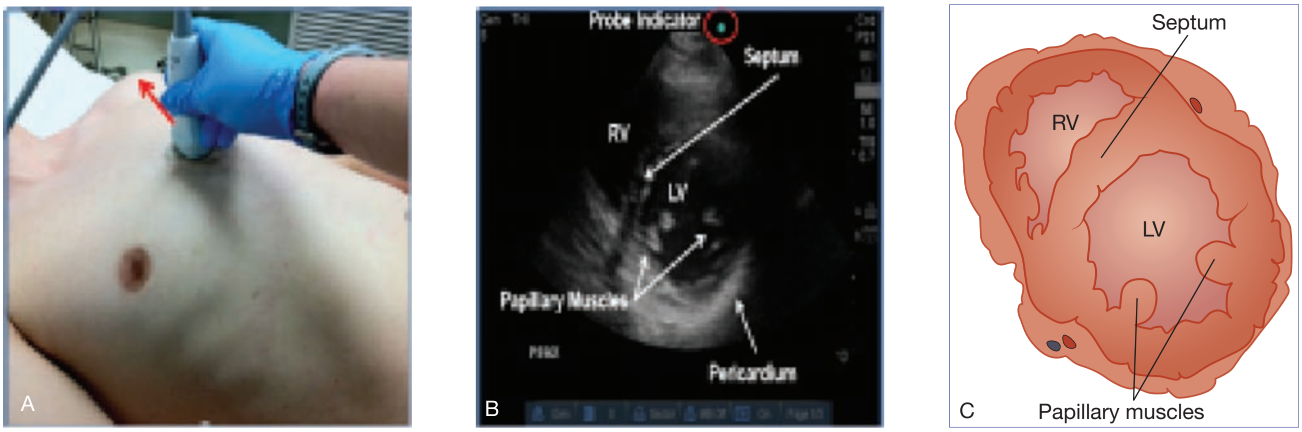
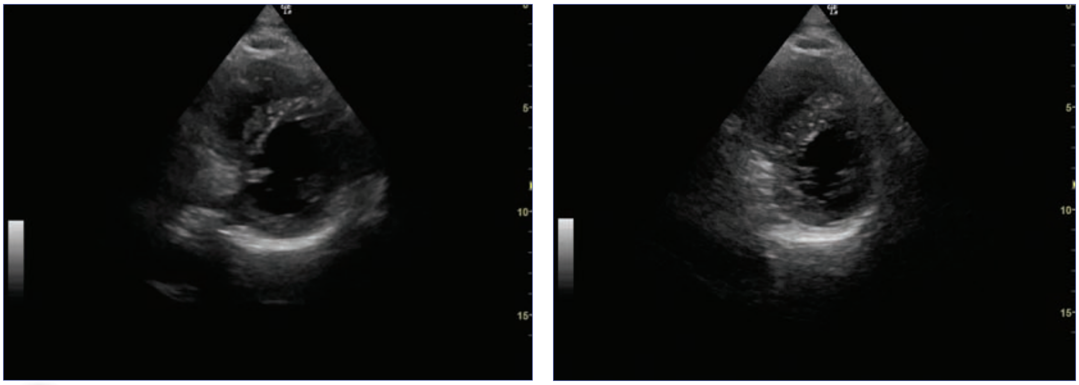

A
Probe Indicator
Septum
RV
LV
Papillary Muscles
Pericardium
B
Septum
RV
LV
C
Papillary muscles

FIGURE 11.9 PSSA view.

Sources: (A) Reproduced with permission from Gibbons, R. (n.d.). *Pericardial effusion.* Retrieved from https://www.saem.org/cdem/education/online-education/m3-curriculum/bedside-ultrasonagraphy/pericardial-effusion; (B) Courtesy of Thomas Costantino.

LV, left ventricle; PSSA, parasternal short axis; RV, right ventricle.



VIDEOS 11.3 AND 11.4 PSSA normal and PSSA with effusion.
PSAX/PSSA, parasternal short axis.
Source: Courtesy of Thomas Costantino.

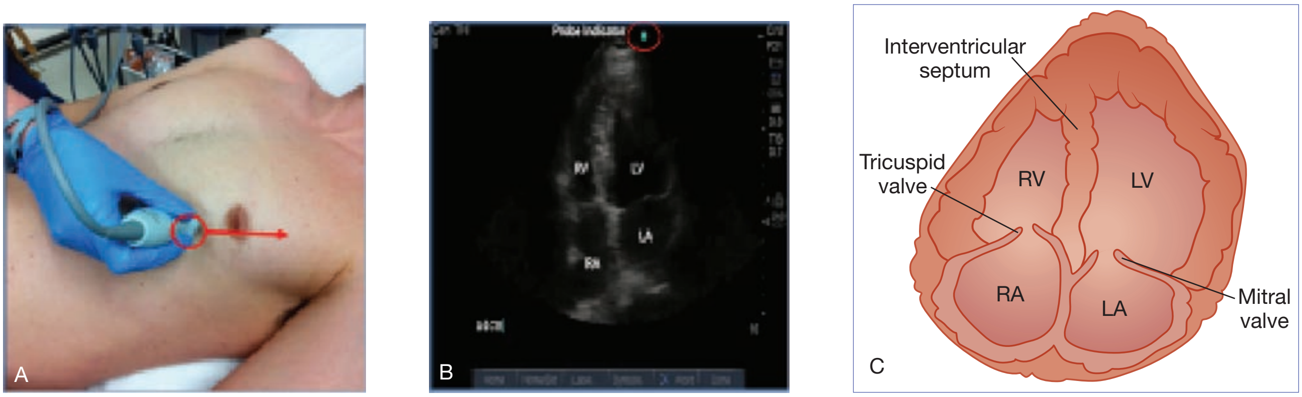

A
B
RV
LV
LA
RA
Interventricular septum
Tricuspid valve
RV
LV
RA
LA
Mitral valve
C

FIGURE 11.10 Apical four chamber view.

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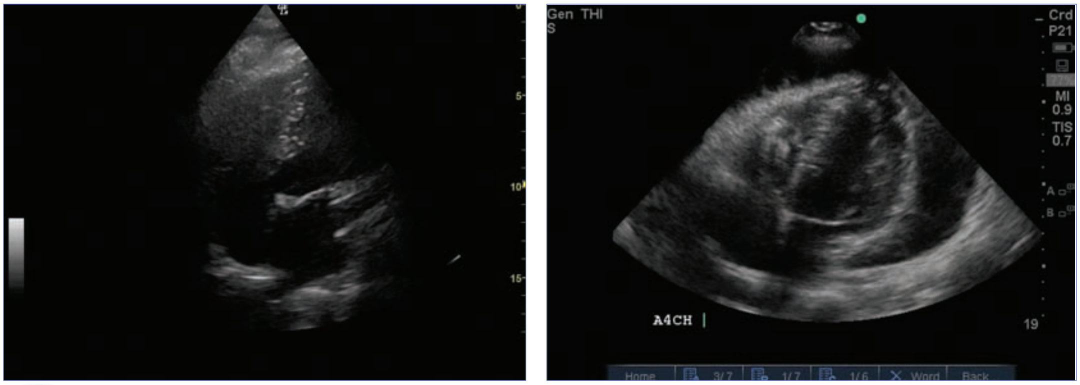
LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.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Crd
P21
MI
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TIS
0.7
A4CH
19
Home
Back

VIDEOS 11.5 AND 11.6 A4Ch normal and A4Ch with effusion.
A4Ch, apical four chamber.
Source: Courtesy of Thomas Costantino.

the heart. Either the phased array or curvilinear (abdominal) probe (**FIGURES 11.11, 11.12, 11.13**) can be utilized to obtain the subcostal view. Use an overhand grip to allow for a shallow approach. Having the patient inhale deeply will bring the heart closer to the probe. Use the liver as your acoustic window and be sure to adjust your depth to visualize the entire heart (**VIDEOS 11.7** and **11.8**).

FOCUS is the diagnostic study of choice for identifying pericardial effusions. It can:

- Detect as little as 15 to 35 mL of pericardial fluid
- Help clarify the type and extent of the effusion
- Recognize tamponade physiology and guide treatment through pericardiocentesis

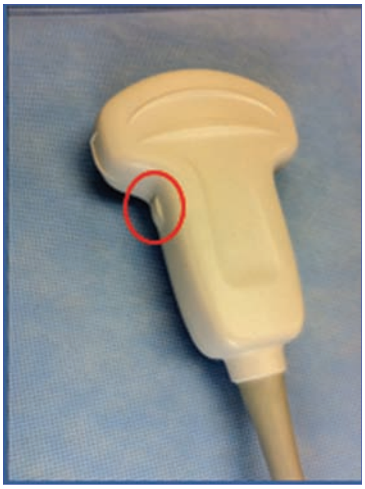


FIGURE 11.11 Curvilinear (abdominal) probe.

Source: Reproduced with permission from Gibbons, R. (n.d.). *Pericardial effusion.* Retrieved from https://www.saem.org/cdem/education/online-education/m3-curriculum/bedside-ultrasonagraphy/pericardial-effusion

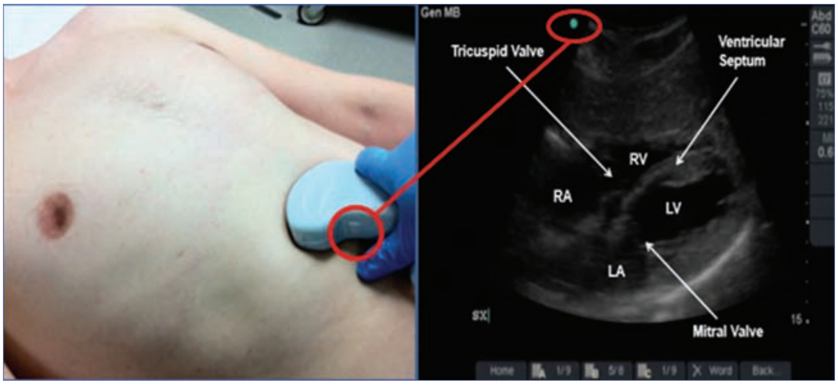


FIGURE 11.12 Subcostal view using the curvilinear (abdominal) probe. When using the curvilinear probe, the indicator is positioned to the patient's right, the traditional point-of-care ultrasound orientation. Use the abdominal setting.

LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Sources: (A) Reproduced with permission from Gibbons, R. (n.d.). *Pericardial Effusion.* Retrieved from https://www.saem.org/cdem/education/online-education/m3-curriculum/bedside-ultrasonagraphy/pericardial-effusion; (B) Courtesy of Thomas Costantino.

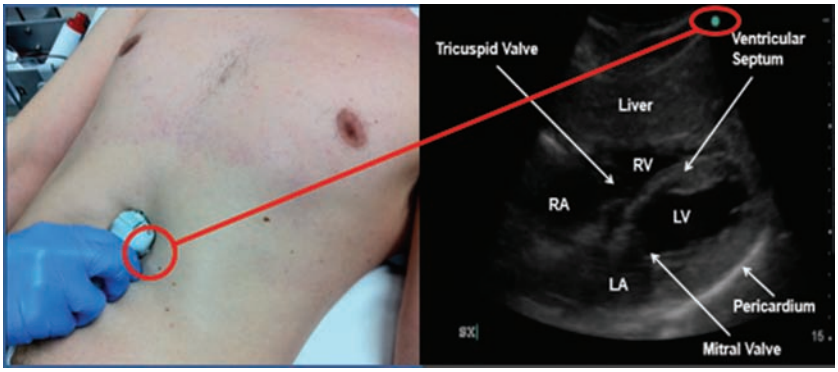
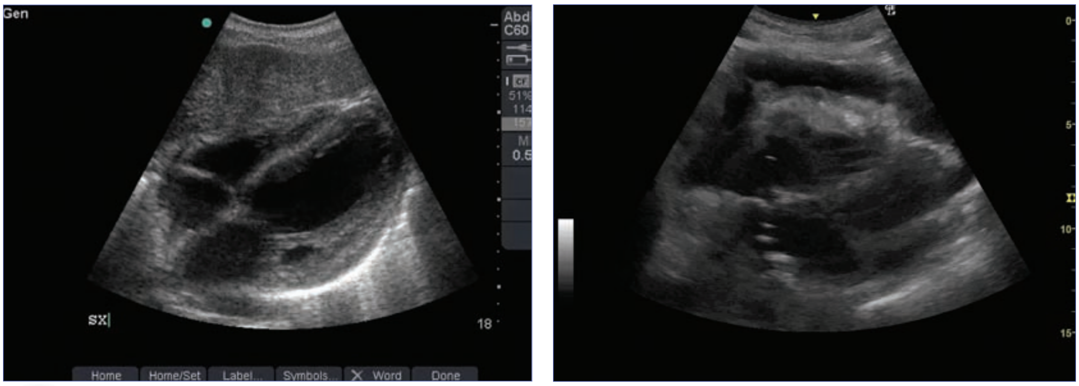


FIGURE 11.13 Subcostal view using the phased-array (cardiac) probe. When using the phased-array probe with the cardiac setting, the indicator is positioned to the patient's left to maintain the traditional view on the ultrasound screen. As stated previously, with the abdominal setting, the probe is oriented toward the patient's right.

LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Sources: (A) Reproduced with permission from Gibbons, R. (n.d.). *Pericardial effusion.* Retrieved from https://www.saem.org/cdem/education/online-education/m3-curriculum/bedside-ultrasonagraphy/pericardial-effusion; (B) Courtesy of Thomas Costantino.



VIDEOS 11.7 AND 11.8 Subxiphoid normal and subxiphoid with effusion.
Source: Courtesy of Thomas Costantino.

Uncomplicated effusion:

- Appears as an anechoic stripe separating the heart from the parietal pericardium, initially accumulating dependently in the posterolateral and inferior sections.

Complex effusions:

- Appear echogenic with internal echoes or septations and may collect circumferentially or focally; usually secondary to infectious or traumatic etiologies. The size or amount of effusion is visually estimated or measured using M-mode at end diastole.

Overall, studies have demonstrated excellent sensitivities and specificities from 96% to 100% for the detection of pericardial effusions in both medical and trauma patients using FOCUS.

- Plummer et al. (1992) not only demonstrated remarkable sensitivity but also a decreased time to the operating room (OR) from 42 to 15 minutes and an improved survival rate from 57% to 100% in patients with penetrating chest trauma with the diagnosis of traumatic pericardial effusions on bedside ultrasound.
- Tayal and Kline (2003) showed survival benefit as well in patients with nontraumatic pulseless electrical activity (PEA) arrest with a bedside ultrasound diagnosis of a pericardial effusion.

PATIENT PRESENTATION

Cardiac Tamponade

All individuals with pericardial effusions are at risk of developing tamponade, which is a potentially fatal complication resulting in obstructive shock. The diagnosis is challenging to all clinicians given that the signs and symptoms of both pericardial effusions and cardiac tamponade can be subtle and not always present. Many patients with pericardial effusions are asymptomatic or have nonspecific signs and symptoms, such as cough, fever, hiccups, fatigue, and abnormal vital signs. ***Moreover, traditionally, we*** are taught that tamponade is a clinical diagnosis and that patients will demonstrate the classic Beck's triad of hypotension; muffled, distant heart sounds; and jugular venous distension (JVD). In reality though, this is a relatively rare and late finding. Less than 10% to 40% patients will present with this triad.

- Medical patients rarely present this way given the chronicity of their diseases.
- Trauma patients are much more likely to depict Beck's triad, although our clinical suspicion is already much higher in this subset of individuals.

Pulsus paradoxus, defined as a drop in systolic blood pressure (SBP) greater than 10 mmHg with inspiration (exaggeration of normal phenomenon) , can be useful in diagnosing cardiac tamponade. However:

- It is time-consuming and difficult with an unstable patient.
- It is not present with significant hypovolemia.
- It is seen in numerous other conditions:
  - Emphysema
  - Pulmonary embolism (PE)
  - Congestive heart failure (CHF)

- Mitral stenosis
- Aortic regurgitation
- Other forms of shock

Given the nonspecific complaints and unreliable exam findings, cardiac tamponade is not just a clinical diagnosis. Utilize FOCUS in conjunction with lung and inferior vena cava (IVC) ultrasound as an adjunct to the physical exam to assess for causes of obstructive shock, such as:

- Tamponade
- Aortic dissection
- Tension pneumothorax

Cardiac tamponade occurs along a spectrum of hemodynamic changes when intrapericardial pressure exceeds intracardiac pressure causing impaired filling, chamber collapse, and decreased cardiac output (CO). This is a form of obstructive shock. The most important factor in developing tamponade physiology is the rate of effusion buildup rather than its size. Gradual accumulation, seen commonly with chronic medical conditions, allows the pericardium to accommodate large volumes in excess of 1 to 2 liters. Several nontraumatic effusions are more likely to develop tamponade though, including those caused by:

- Bacterial infections
- Neoplasms
- Post radiation

Regardless of etiology, nearly one-third of chronic large effusions progress to obstructive shock.

Traumatic effusions accrue rapidly preventing the pericardium to adapt. Subsequently, cardiac tamponade occurs in these situations with as little as 50 to 100 mL of fluid. The pericardial compliance determines the amount of fluid that triggers tamponade. Dr. David Spodick described tamponade as a "last-drop" phenomenon: "the final increment produces critical cardiac compression, and the first decrement during drainage produces the largest relative decompression" (**FIGURE 11.14**). **TABLES 11.7** and **11.8** review the common causes of tamponade as well as the characteristic ultrasound findings (**FIGURES 11.15–11.20; VIDEOS 11.10–11.14**).

Pathologic ventricular chamber collapse occurs during ventricular diastole (atrial systole), whereas pathologic atrial collapse occurs during ventricular systole (atrial diastole). Utilize M-mode in the PSLA or subxiphoid view to help identify diastole by correlating with the peak E-wave amplitude or replay videos to identify when the mitral (PSLA or A4Ch view) and/or tricuspid (A4Ch view) valves are fully open (**see FIGURES 11.16–11.20**).

Many of these ultrasound findings can be challenging to identify on FOCUS, therefore consider tamponade strongly if the patient is hypotensive with a pericardial effusion.

Transvalvular pulsed-wave Doppler inflow velocities are challenging even for advanced clinicians and routinely do not add much with respect to the diagnosis of tamponade pathology. The pathophysiology and method used to measure these values are beyond the scope of this review.

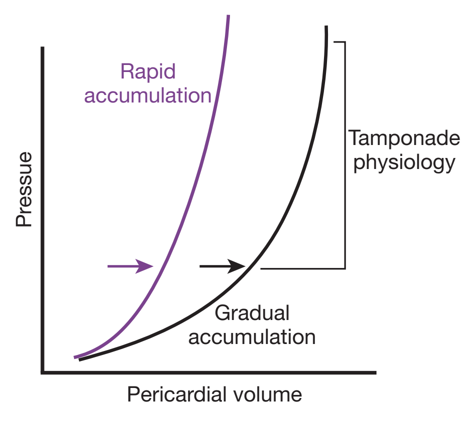


FIGURE 11.14 Tamponade pathophysiology.

Source: Reproduced with permission from Gibbons, R. (n.d.). *Pericardial Effusion.* Retrieved from https://www.saem.org/cdem/education/online-education/m3-curriculum/bedside-ultrasonagraphy/pericardial-effusion

TABLE 11.7 Causes of Tamponade

Common	Less Common
Trauma Iatrogenic ■ Cardiac surgery or catheterization Neoplasm ■ >50% of tamponade cases ■ Lung cancer most common Infectious ■ Tuberculosis Pericarditis	Autoimmune Myocardial Infarction AoD Radiation Uremia

AoD, aortic dissection.

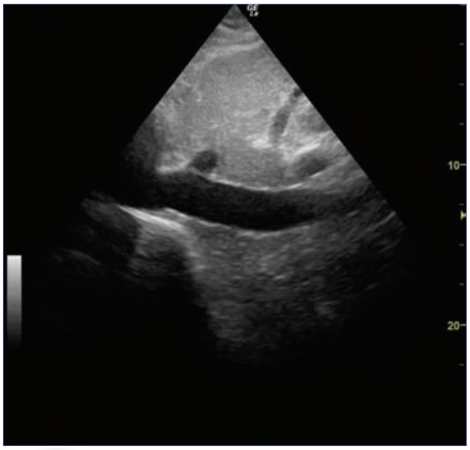
TABLE 11.8 Ultrasound Findings in Tamponade

RV collapse ■ During ventricular diastole ■ Hallmark finding ■ Increased specificity ■ RVOT (PSLA view) is the most compressible area *RA collapse* ■ During early ventricular systole ■ More common ■ Occurs earlier than RV collapse ■ Collapse for >1/3 cardiac cycle is highly specific ■ Extends to late ventricular end diastole as well *IVC plethora* (**VIDEO 11.9** and **FIGURE 11.15**)[*] ■ Decreased respirophasic variation <50% ■ No collapse ■ 97% sensitive, lacks specificity	*Increased respiratory variation of transvalvular peak inflow velocities*[**] ■ >25% inspiratory decrease of mitral E-wave signal ■ >40% inspiratory increase of tricuspid E-wave signal *Large effusion with swinging heart* ■ Known as *electrical alternans* (**VIDEOS 11.10** and **11.11**) ■ Usually >300 to 600 mL *LA collapse* ■ 98% specificity ■ Generally, a late finding ■ Only 25% of cases *LV collapse* ■ Very rare ■ Most often loculated and/or post surgery

[*] Visual estimation or measured with M-mode about 2 to 3 cm distal from its entrance into the right atrium or just distal to where the right hepatic vein joins the IVC (**see VIDEO 11.9** & **FIGURE 11.15**).

[**] Focused cardiac ultrasound finding equivalent to pulsus paradoxus. Measure the E-wave amplitude with pulsed wave Doppler in the A4Ch view during early diastolic filling.

A4Ch, apical four chamber; IVC, inferior vena cava; LA, left atrium; PSLA, parasternal long axis; RA, right atrium; RV, right ventricle; RVOT, right ventricular outflow tract.



VIDEO 11.9 IVC plethora without respirophasic variation.

IVC, inferior vena cava.

Source: Courtesy of Thomas Costantino.

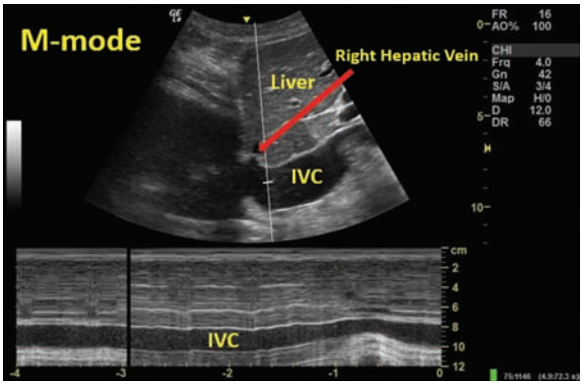


FIGURE 11.15 M-mode used to evaluate IVC respirophasic variation (complete lack of variation; IVC plethora).

IVC, inferior vena cava.

Source: Courtesy of Thomas Costantino.

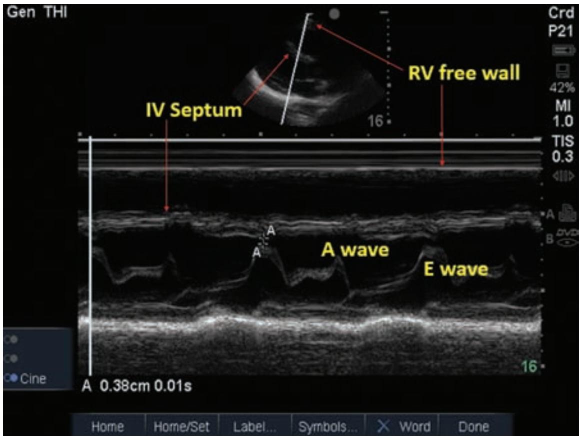


FIGURE 11.16 PSLA view. Use M-mode to evaluate for RV collapse during ventricular diastole (no collapse). The top of the image demonstrates ventricular systole. M-mode depicts the entire cardiac cycle.

IV, intraventricular; PSLA, parasternal long axis; RV, right ventricle.

Source: Courtesy of Thomas Costantino.

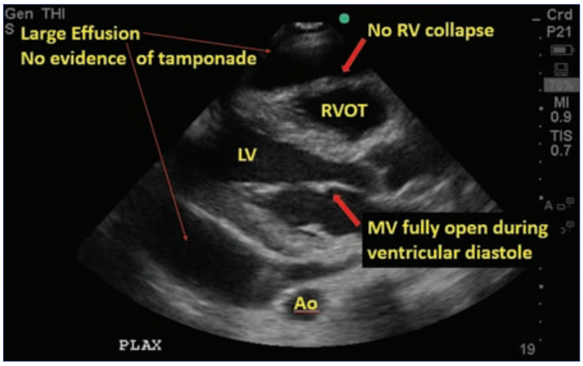

Gen THI
S
Large Effusion
No evidence of tamponade
No RV collapse
Crd
P21
MI
0.9
TIS
0.7
RVOT
LV
MV fully open during ventricular diastole
Ao
PLAX
19

FIGURE 11.17 PSLA view of ventricular diastole with large circumference effusion without tamponade.

LV, left ventricle; PSLA, parasternal long axis; RVOT, right ventricular outflow tract.

Source: Courtesy of Thomas Costantino.

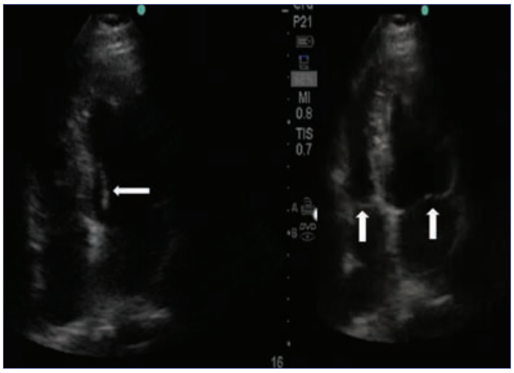

P21
MI
0.8
TIS
0.7
16

FIGURE 11.18 A4Ch view of ventricular diastole with mitral and tricuspid valves open (*left*) and ventricular systole with mitral and tricuspid valves closed (*right*).

A4Ch, apical four chamber.

Source: Courtesy of Thomas Costantino.

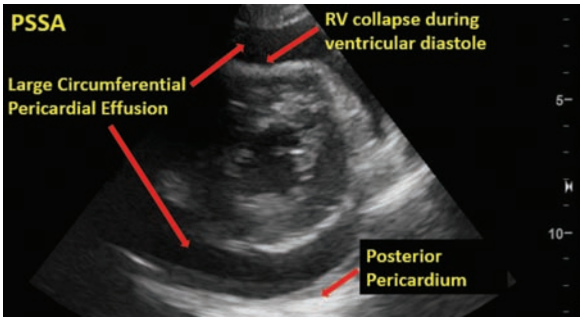

PSSA
RV collapse during ventricular diastole
Large Circumferential Pericardial Effusion
5
10
Posterior Pericardium

FIGURE 11.19 PSSA view of RV collapse during ventricular diastole with large circumferential effusion.

PSSA, parasternal short axis, RV, right ventricle.

Source: Courtesy of Thomas Costantino.

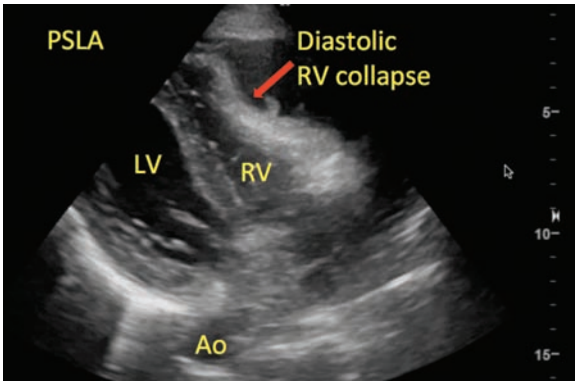
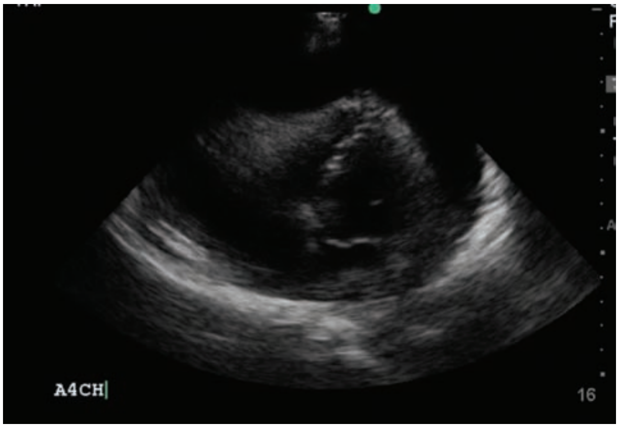

PSLA
Diastolic RV collapse
LV
RV
5
10
Ao
15

FIGURE 11.20 Diastolic RV collapse secondary to loculated anterior pericardial effusion.

Ao, aorta; LV, left ventricle; PSLA, parasternal long axis; RV, right ventricle.

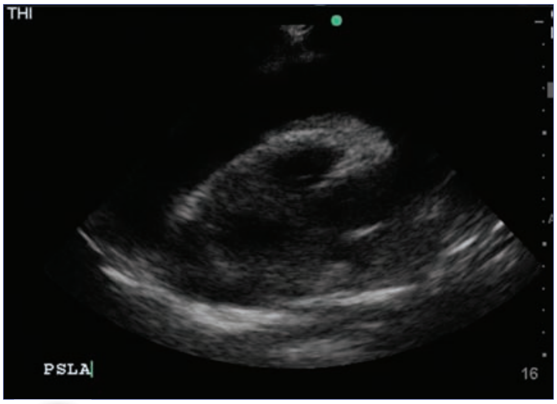
Source: Courtesy of Thomas Costantino.



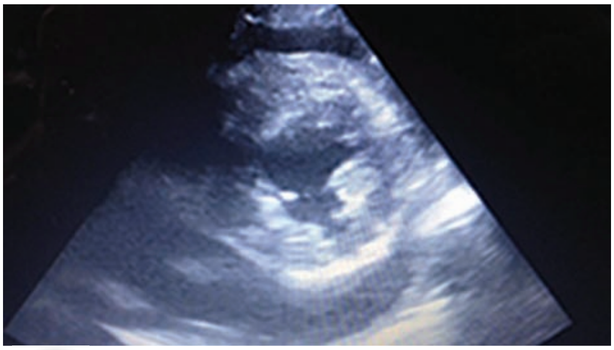
VIDEO 11.10 A4Ch with electrical alternans.

A4Ch, apical four chamber.

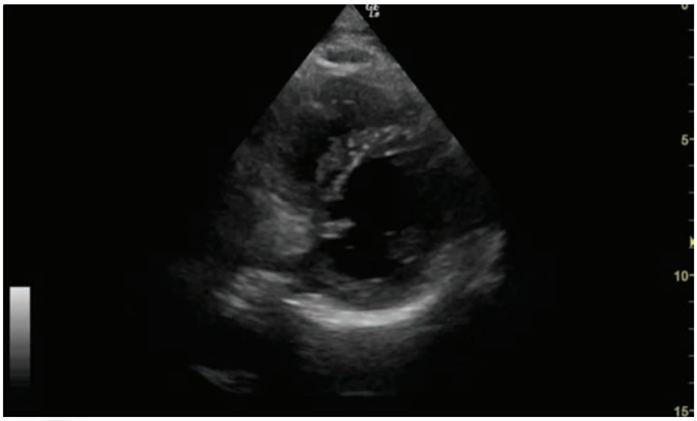
Source: Courtesy of Thomas Costantino.



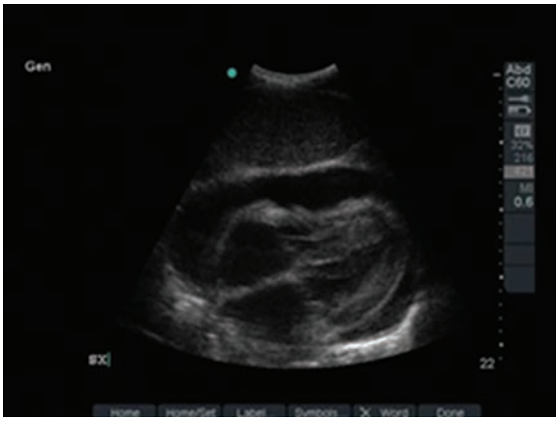
VIDEO 11.11 PSLA with electrical alternans.
PSLA, parasternal long axis.
Source: Courtesy of Thomas Costantino.



VIDEO 11.12 PSSA with large effusion and tamponade physiology.
PSSA, parasternal short axis.



VIDEO 11.13 PSLA with large effusion and tamponade physiology.
PSLA, parasternal long axis.



VIDEO 11.14 Subcostal view with large effusion and tamponade physiology.

Pericardiocentesis

There are essentially only two indications for pericardiocentesis:

- Diagnostic in cases of nontamponade
  - Elective
- Therapeutic in cases of tamponade
  - Emergent
    - Temporizing procedure
  - Potentially life-saving procedure in the coding or hemodynamically unstable patient Unfortunately, it is a rare and risky procedure that few emergency clinicians practice routinely
- Traditionally, we are taught to use the blind subcostal (subxiphoid) approach, however (**FIGURE 11.21**):
  - Tsang et al. (2002) conducted a 21-year retrospective review at the Mayo clinic and demonstrated a 97% success rate with ultrasound guidance with substantially fewer complications.
  - Furthermore, only 20% of the time was the subcostal approach the ideal one.
  - Clinicians had far greater success with the A4Ch method.
- Multiple views are advised to identify the optimal approach, which is wherever the fluid is closest to the probe

An emergent pericardiocentesis can be a temporizing measure in the hemodynamically unstable patient without access to a cardiac catheterization lab or surgical specialties. In a medical cardiac arrest patient with an effusion, pericardiocentesis is immediately warranted.

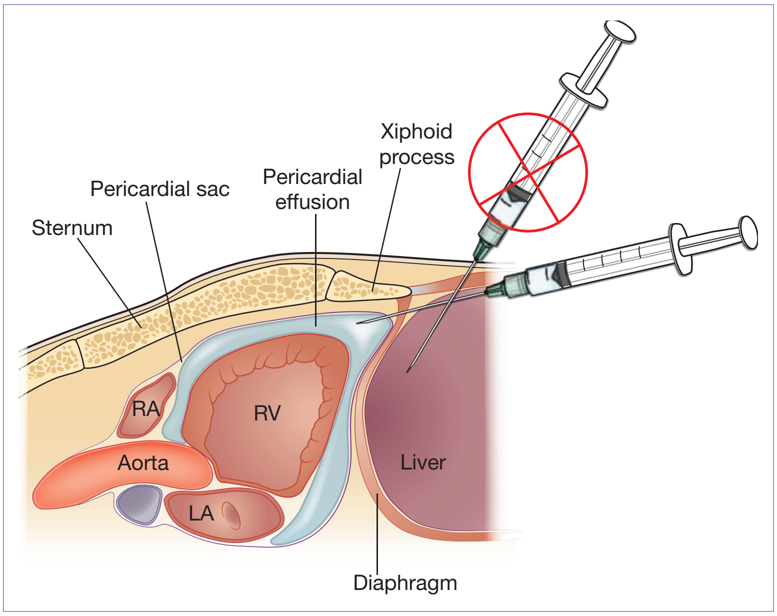


FIGURE 11.21 Needle direction with a subxiphoid technique. Note the heart is very anterior and a 45-degree entry angle brings the tip of the needle too close to the liver and stomach and may inadvertently penetrate the liver and/or other noncardiac structures; try to maintain an angle no greater than 30 degrees.

LA, left atrium; RA, right atrium; RV, right ventricle.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

None

SPECIAL CONSIDERATIONS

Agitated Saline

- Proper needle placement can be further confirmed by injecting saline that has been shaken to produce bubbles, known as *agitated saline*.
- The bubbles show well on the ultrasound as they are quite echogenic (**FIGURE 11.22**).

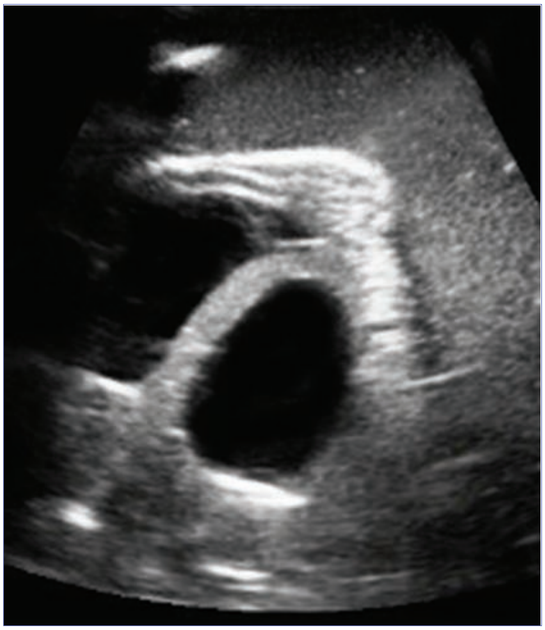


FIGURE 11.22 Pericardiocentesis with assurance of needle placement in the pericardial sac and not elsewhere via injection of agitated saline. Note the generation of echogenicity in the pericardium.

Source: Courtesy of Thomas Costantino.

PROCEDURE PREPARATION

- The patient should be supine with the head of the bed (HOB) elevated to 30 degrees to permit better access to fluid collections
- The left lateral decubitus position may improve your visualization as well
- Intravenous fluids can be given while prepping for the procedure in an effort to augment CO
- Sterile gloves, mask, and gown
- Sterile drapes
- Local anesthesia
- Chlorhexidine or betadine solution
- 20-mL syringe
- 5-cm 16-gauge needle catheter
- Three-way stopcock
- Pericardiocentesis pigtail catheter kit
- Ultrasound machine with cardiac probe and sterile cover (**FIGURES 11.23** and **11.24**)

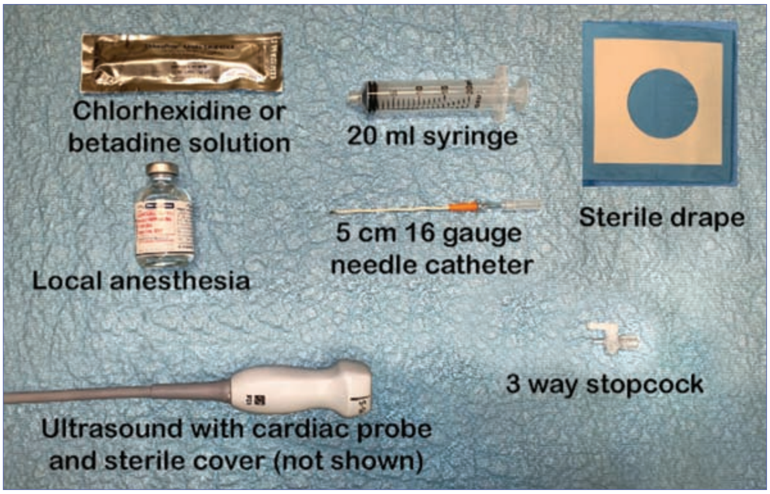

Chlorhexidine or betadine solution
20 ml syringe
Sterile drape
Local anesthesia
5 cm 16 gauge needle catheter
3 way stopcock
Ultrasound with cardiac probe and sterile cover (not shown)

FIGURE 11.23 Equipment required for the needle-syringe method.

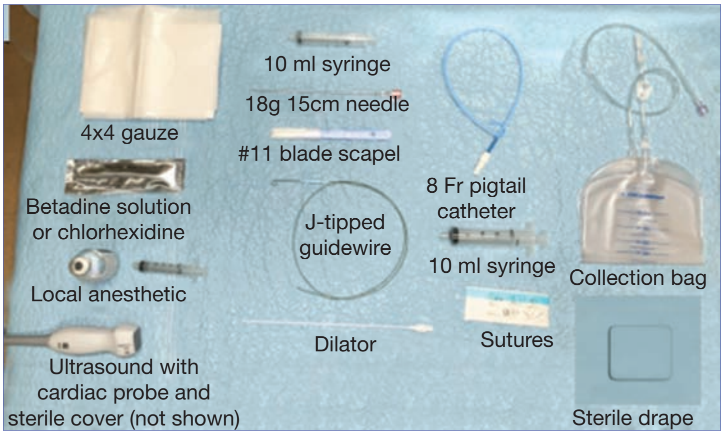

4x4 gauze
10 ml syringe
18g 15cm needle
#11 blade scapel
8 Fr pigtail catheter
Betadine solution or chlorhexidine
J-tipped guidewire
10 ml syringe
Collection bag
Local anesthetic
Dilator
Sutures
Ultrasound with cardiac probe and sterile cover (not shown)
Sterile drape

FIGURE 11.24 Pigtail catheter Seldinger pericardiocentesis kit.

PROCEDURE

Needle-Syringe Method

- Ensure sterile wardrobe (mask, hat, gown, gloves, and eye shield).
- Use skin cleanser on chest and abdominal area.
- Place sterile drapes on patient.
- Use a 5-cm 16-gauge needle catheter with ultrasound guidance to ensure its location within the pericardial sac.
  - The location and direction of the ultrasound waves should be fixed in the mind of the person performing the pericardiocentesis, and the needle is advanced similarly.
  - In-plane ultrasound guidance allows the needle to be seen in its entire track; entry point should be at the end of the probe.
  - The largest pocket of fluid will often be located somewhere between the traditional transducer position for a parasternal view and an A4Ch view.
- Make sure to advance over the cephalad portion of the rib inferior to your insertion point, avoiding the neurovascular bundle below the rib above.
- Insert the needle toward the largest fluid collection with your dominant hand while applying constant back pressure on the plunger.
  - Note that the internal mammary artery lies 2 to 4 cm lateral to the sternum; attempt to use needle entry points away from this area.
  - The internal mammary artery (IMA) can be visualized with color Doppler; attempt to identify and mark the site of the IMA with a sterile pen before you insert your needle (**see FIGURE 11.25**).
  - Note the trajectory of the ultrasound beam with regard to the best image, as the needle trajectory should be similar.
- Entry point is again accomplished with direct ultrasound visualization based on the best view of fluid.
  - A4Ch view (**FIGURE 11.26**)
    - Best approach as it has the highest success rate
    - The lingula portion of the left lung lies near the apex of the heart so again use the ultrasound
  - Subxiphoid (**FIGURE 11.27**)
  - PSLA (**FIGURE 11.28**)
    - Nagdev and Mantuani (2013) described a novel in-plane technique via the PLSA; refer to the Resources section for a detailed review.
- Once fluid is aspirated, advance the plastic catheter fully until the hub abuts the skin.
  - The addition of the flexible catheter sheath allows the needle to be removed (safer) for repeated drainage if
  - needed.
  - Check the placement of the catheter with ultrasound.
- Attach a three-way stopcock and syringe.
- Aspirate the fluid, being cognizant to turn the stopcock to the off position when replacing the syringe.
  - Note that in a tamponade, even the removal of 10 mL may give rise to a significant increase in cardiac output.

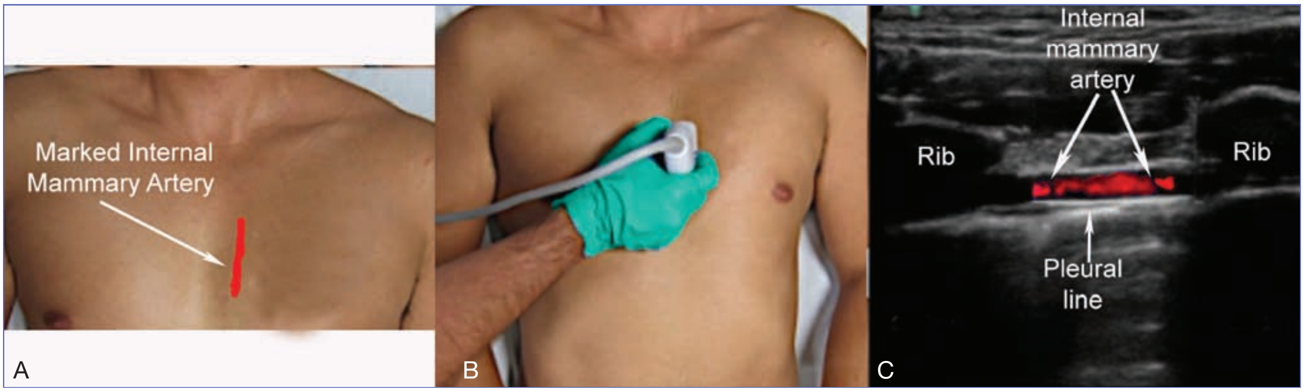


FIGURE 11.25 If there is time and the clinician is not using the subxiphoid approach, identify with Doppler and mark the internal mammary artery.

Source: (C) Courtesy of Thomas Costantino.

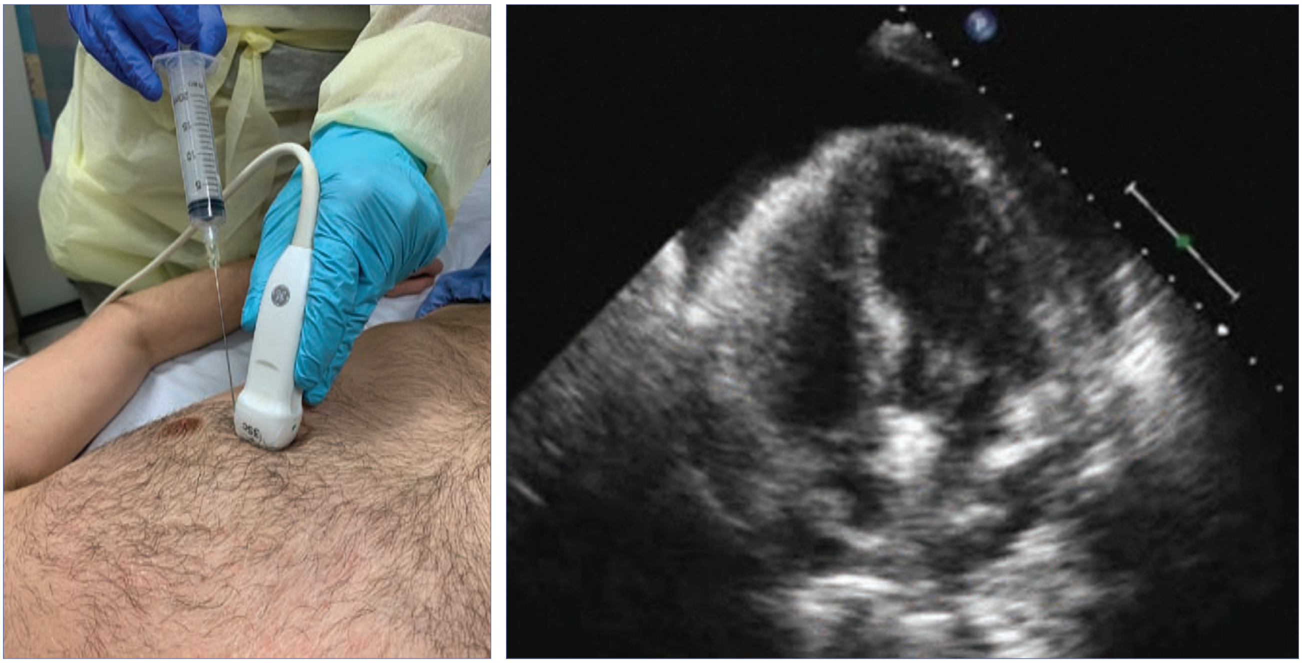


FIGURE 11.26 FOCUS-guided pericardiocentesis. A4Ch in-plane technique.
A4Ch, apical fourth chamber; FOCUS, focused cardiac ultrasound.

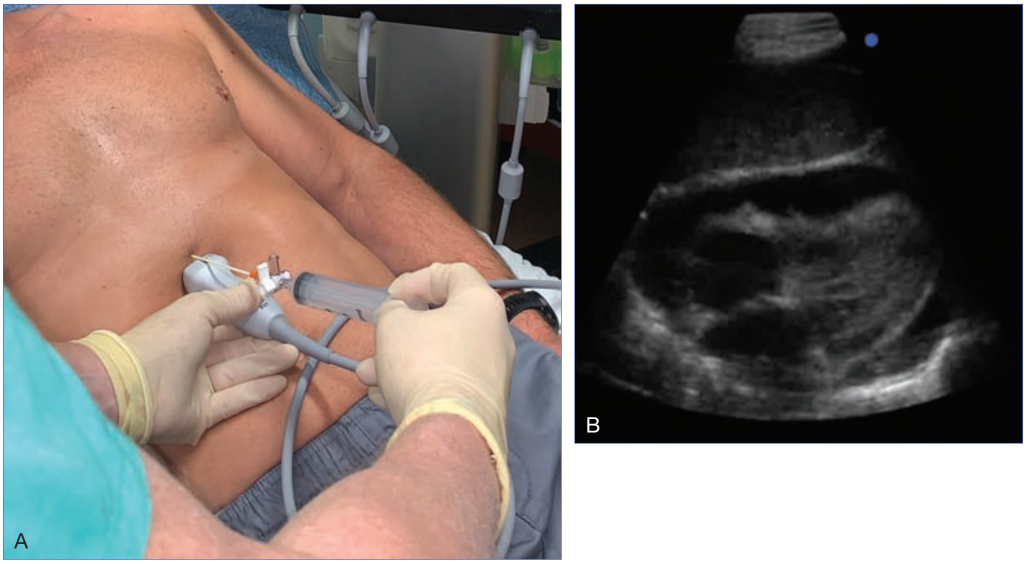


FIGURE 11.27 (A) FOCUS-guided pericardiocentesis. (B) An image of a subxiphoid out-of-plane technique.
FOCUS, focused cardiac ultrasound.

Pigtail Catheter Seldinger Method

- Alternatively, one may use the pigtail catheter Seldinger technique (**VIDEO 11.15**) for continued drainage as there is a 30% recurrence rate.
- Ensure sterile drapes are placed, skin is cleansed, and local anesthesia is provided (**FIGURE 11.29**).
- Using back pressure on the plunger, insert needle toward the direction of the largest fluid collection (**FIGURE 11.30**).

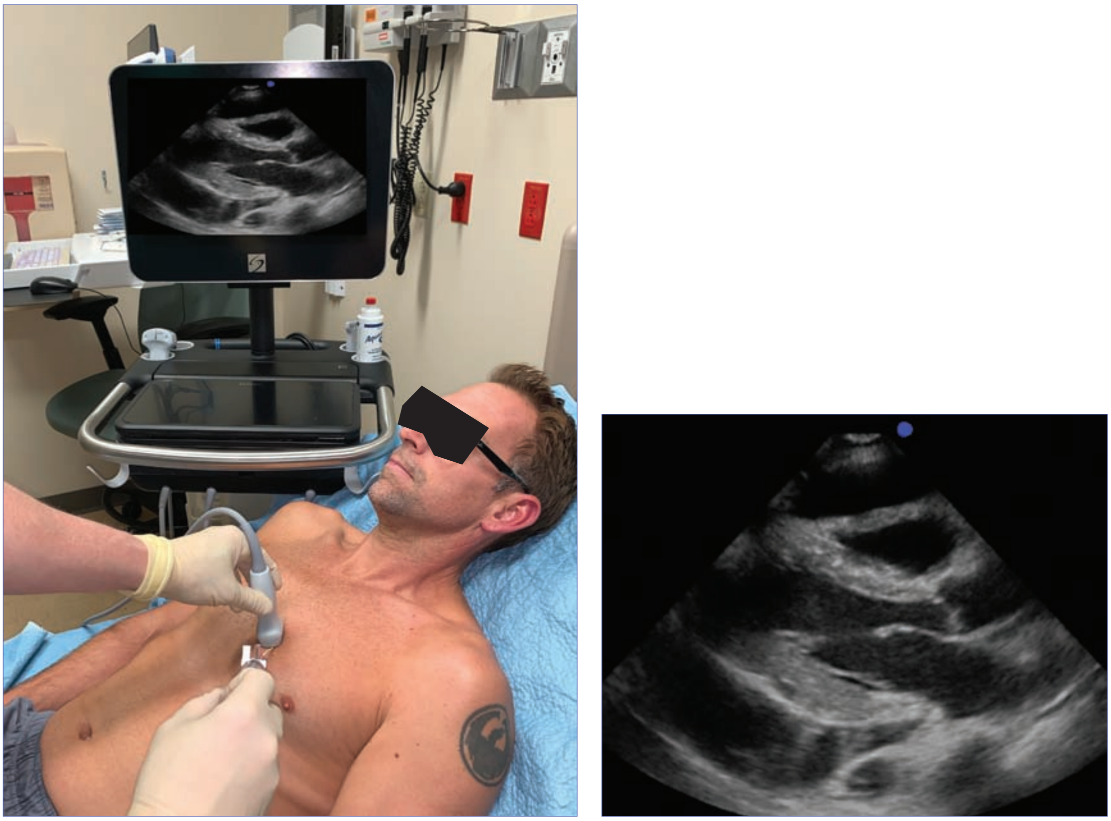
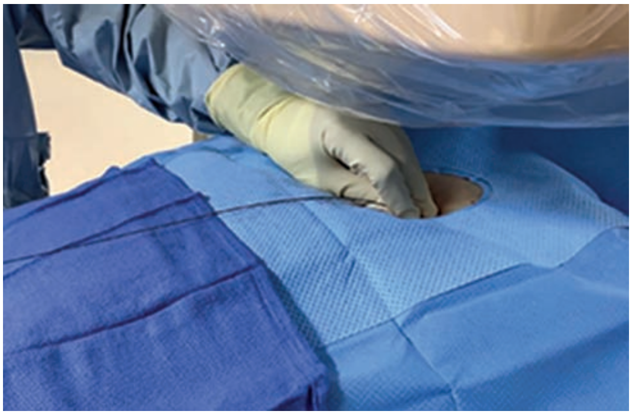

[redacted]

FIGURE 11.28 FOCUS-guided pericardiocentesis. PSLA in-plane technique. FOCUS, focused cardiac ultrasound; PSLA, parasternal long axis.



VIDEO 11.15 Pericardiocentesis using a pigtail catheter and guided by ultrasound.

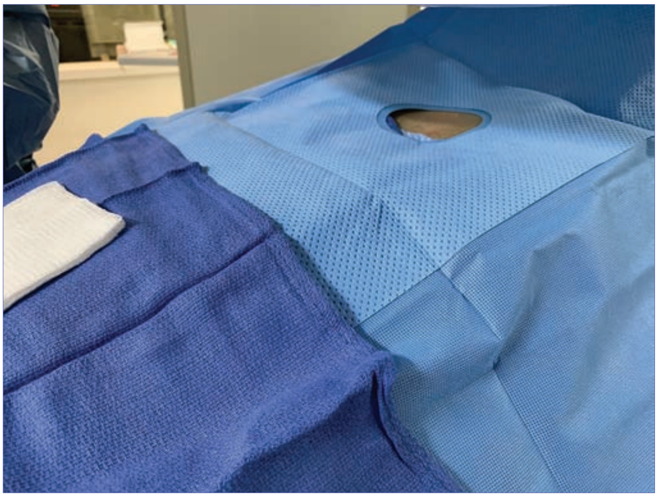


FIGURE 11.29 Sterile drapes. Note that skin cleansing and administration of local anesthesia are not shown.

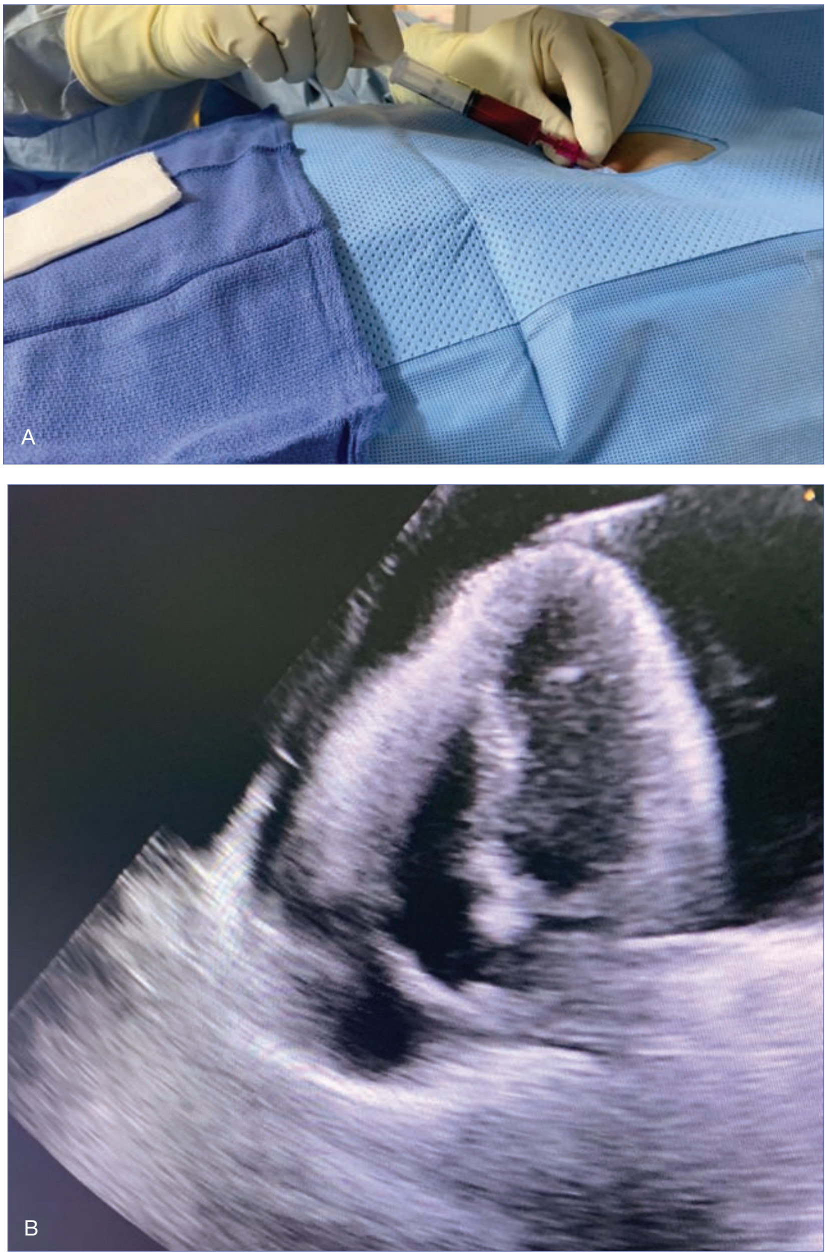
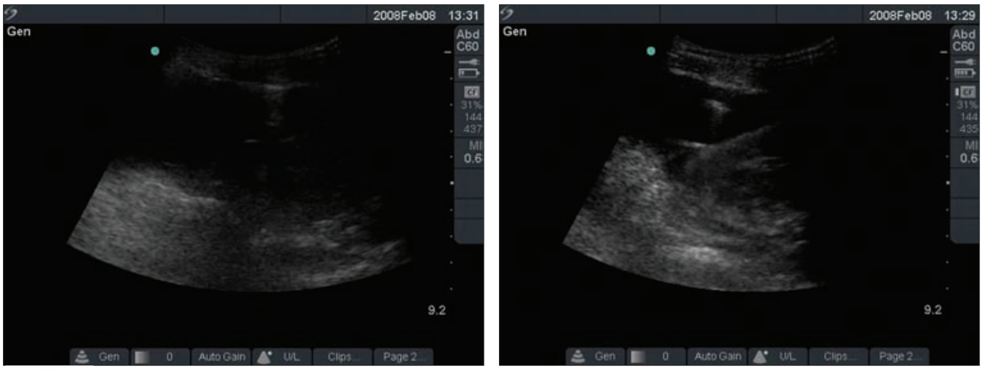


FIGURE 11.30 Needle aspiration. Note this is being done under ultrasound guidance; not shown is an assistant using the apical four-chamber view with the probe under the sterile drapes. Note the needle inside the pericardial sac just inferior to the apex.

Source: (B) Courtesy of Thomas Costantino.

- Usually, the A4Ch view is best at showing the fluid collection; however, one may also use the subxiphoid and/or PSLA view as well, depending on what view shows the largest amount of fluid (**VIDEOS 11.16A** and **11.16B**).
- Upon pericardial fluid return, remove the needle and insert the wire (**FIGURE 11.31**). Never let go of the wire! Note most of the wire will not need to and should not be inserted into the needle. Once wire is in place, confirm the placement of the wire in the pericardial sac (and confirm it is not in a cardiac chamber) via ultrasound before inserting the dilator.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Gen
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VIDEOS 11.16A AND 11.16B Needle entry during a pericardiocentesis.
Source: Courtesy of Thomas Costantino.

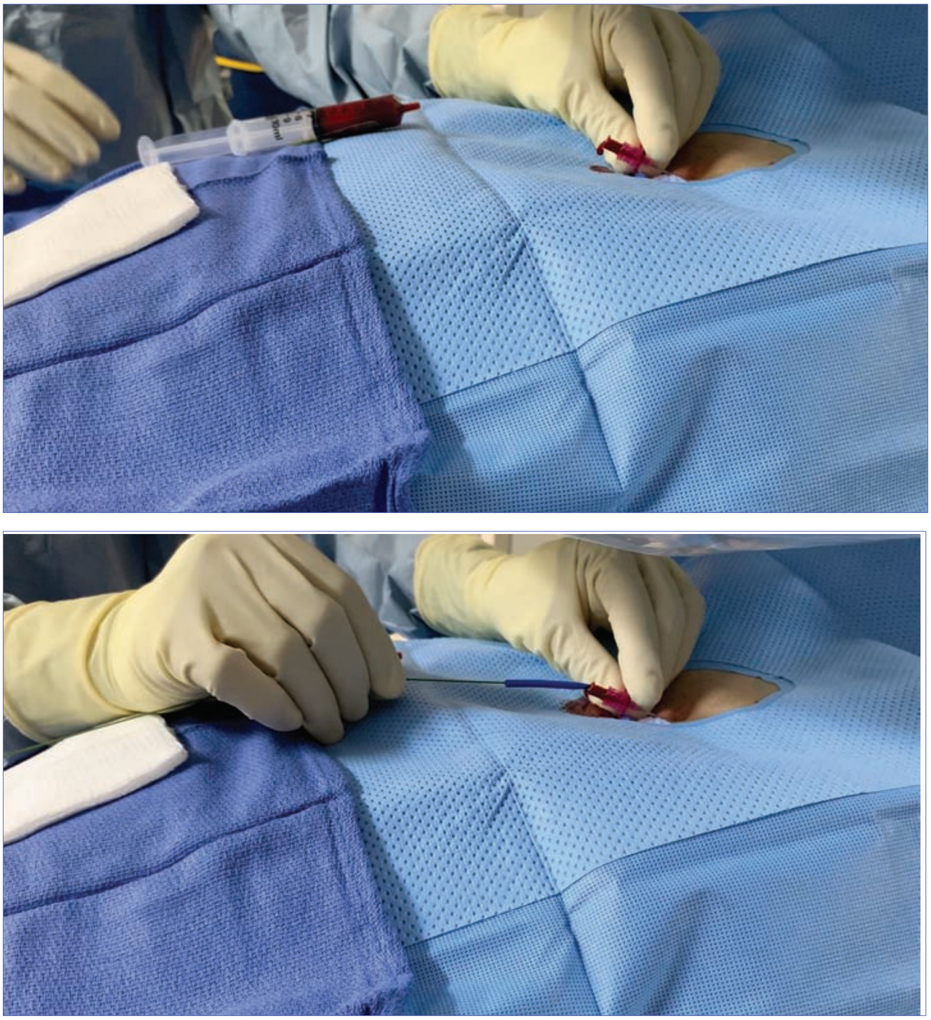


FIGURE 11.31 Wire insertion through the needle and into the pericardial sac.

- Not shown in the pictures is the small-stab skin incision with a No. 11 blade scalpel to help facilitate the passing of the dilator. After this skin-stab incision at the area of the skin lying next to the wire, firmly hold the distal end of the wire with your nondominant hand and place the dilator over the proximal end of the wire advance through the skin twisting the distal dilator as it enters the skin (**FIGURE 11.32**). After dilation, remove the dilator ensuring the wire is always grasped.
- While holding the wire with your nondominant hand, use your dominant hand to place the pigtail catheter over the wire into the pericardial sac (**FIGURE 11.33**). Twist the distal pigtail catheter to help insert it through the skin. When one starts to see the proximal end of the wire illuminate from the proximal part of the pigtail catheter, remove the wire completely. Never let go of the wire.
- Attach to tubing, three-way stopcock, and a collection/drainage device (**FIGURE 11.34**)

Surgical Evacuation

Surgical evacuation is optimal for:

- Posterior effusions
- Nonuniform (loculated or focal) effusions
- Complex effusions
- Thrombosed effusions
- Traumatic effusions are best managed with surgical intervention
    - Surgical Intervention in ED or OR depending on hemodynamic stability.

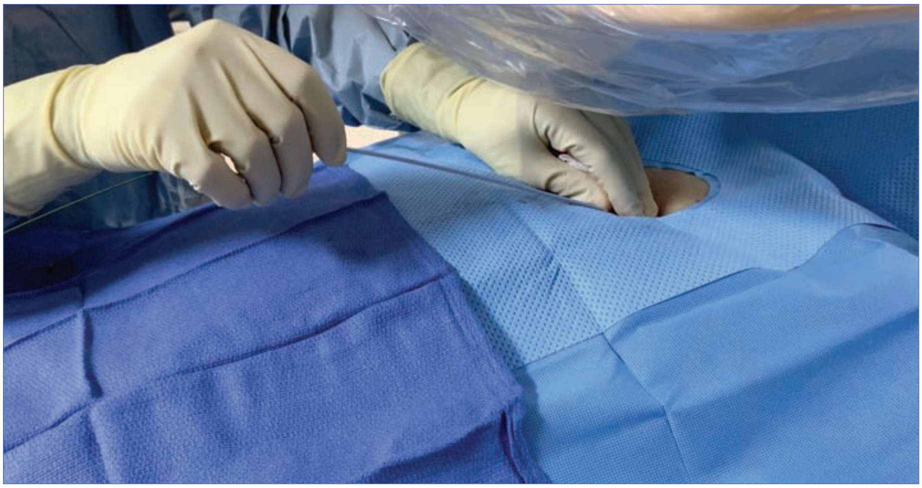


FIGURE 11.32 Dilation of the skin structures over the wire. Note prior to this step and not shown is the scalpel skin incision, where the wire meets the skin.

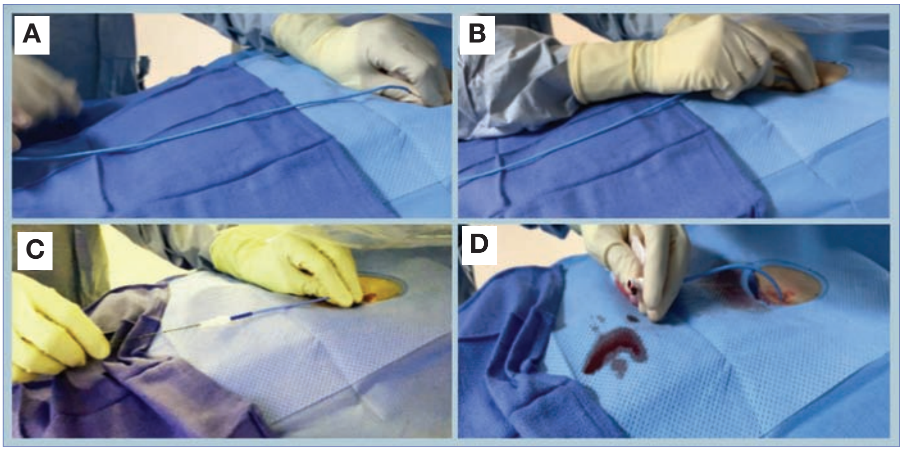


FIGURE 11.33 Placement of the pigtail catheter over the wire and into the pericardial sac. Ensure the wire is never released and that it is removed completely as the pigtail catheter is advanced.

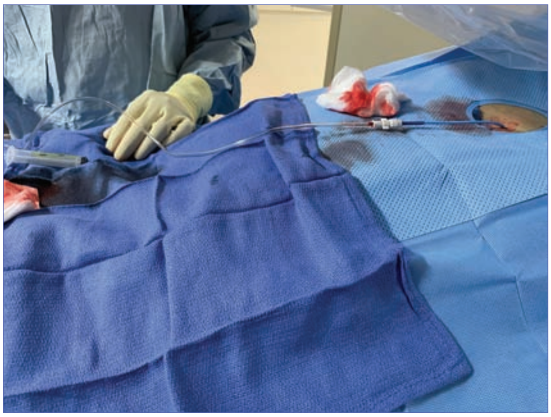


FIGURE 11.34 Successful pigtail placement into the pericardial sac.

POSTPROCEDURE CONSIDERATIONS

- Immediate specialty consultation (cardiology, cardiothoracic, trauma)
- Manage complications (i.e., chest tube, antibiotics, etc.)
- Need for repeat pericardiocentesis
- Transfer to cardiac catheterization lab, OR, appropriate intensive care unit (cardiac or surgical)

EDUCATIONAL POINTS

- Patient body habitus and stability, lung artifact, chest wall injuries, and ongoing procedures or resuscitation can obscure cardiac visualization; be sure to utilize all four standard views and make subtle changes to your probe placement and orientation along with patient positioning to optimize your views through the intercostal spaces (**TABLE 11.9**).
- Rotating, angling, and tilting your probe, as well as trying advanced views (as your training progresses), can facilitate your scans (**TABLE 11.10**).
- Placing the patient's left hand overhead may widen the intercostal spaces.
- Remember, patients' anatomies vary; go where the fluid is as this leads to the most success.
- Adjust your probe placement as needed by sliding cranially and caudally along the left parasternal border between the second and fifth intercostal spaces; even moving to the right parasternal border may improve your images.

TABLE 11.9 Maneuvers to Augment Cardiac Visualization

	PSLA	PSSA	A4Ch	Subcostal
Inhale				X
Exhale	X	X	X	
Supine (HOB 30° upright)	X	X		X (completely supine)
Left lateral decubitus	X		X	

A4Ch, apical fourth chamber; HOB, head of bed; PSLA, parasternal long axis; PSSA, parasternal short axis.

TABLE 11.10 Cardiac Anatomic Position in the Chest Cavity

	Medial	Lateral	Higher	Lower
Younger	X		X	
Elderly		X		X
Low BMI				X
Obese			X	

BMI, body mass index.

- Left ventricle (LV) collapse may occur in tamponade as the reduction in forward flow (from the right ventricle [RV]) decreases blood return to the left atrium (LA)/LV and one may see a hyperdynamic LV with wall-to-wall contractions; ejection fractions may near 100%.
- The A4Ch view is the most technically challenging one.
  - Move the patient into the left lateral decubitus position to bring the heart closer to the chest wall in order to supplement your view.
  - Nonetheless, 25% to 30% of individuals will not have a visible A4Ch view.
- Remember, only 10% to 40% of patients with cardiac tamponade will present with the classic Beck's triad of distant, muffled heart sounds; JVD; and hypotension.
  - Utilize FOCUS in conjunction with lung and IVC ultrasound to supplement your physical exam.
- Pulsus paradoxus is seen in numerous other conditions, such as emphysema, pulmonary embolism, congestive heart failure, mitral stenosis, and aortic regurgitation.
  - It is often absent in severe hypovolemia.
- Rate of accumulation, rather than size, is the most important determinant of cardiac tamponade.
  - Traumatic, neoplastic, infectious, and iatrogenic effusions are most likely to precipitate obstructive shock.
- Utilize all standard (and nonstandard) views to avoid missing focal, loculated, and small effusions, which can all cause tamponade physiology.
- The anterior epicardial fat pad is a heterogenous hypoechoic tissue with internal echoes that moves in conjunction with cardiac activity (**TABLE 11.11**).
  - It is not circumferential and not clinically significant.
  - Normally, it is found in obese and elderly patients.
  - The fat pad is best seen above the right ventricular outflow tract (RVOT) in the PSLA view.
  - Again, employ multiple views to differentiate between the anterior fat pad and pericardial effusions.
  - Loculated and focal effusions can be particularly challenging to distinguish from an epicardial fat pad; the latter normally will have no impact on the patient's hemodynamic status, whereas the former can cause hemodynamic compromise.
- Differentiating between pleural and pericardial can be challenging.
  - Identify the descending aorta in the PSLA view (**FIGURE 11.35**).
  - Pericardial effusions track along the heart and separate the aorta from the pericardium and cross the midline.

TABLE 11.11 **Pericardial Effusions**

False Positives	False Negatives
■ Epicardial fat pad ⇨ Anterior ⇨ @RVOT in PSLA view ⇨ Moves with cardiac activity ⇨ Best seen in systole ⇨ Not seen in diastole ■ Pleural effusion* ■ Ascites ■ Thrombus ■ Mass ■ Left Ventricular Aneurysm	■ Hemorrhagic effusion ■ Clot ■ Loculated effusion ■ Focal effusion

*Large pleural effusions can cause tamponade physiology. Intrathoracic pressure is transmitted to pericardial sac. Consider thoracentesis.

PSLA, parasternal long axis; RVOT, right ventricular outflow tract.

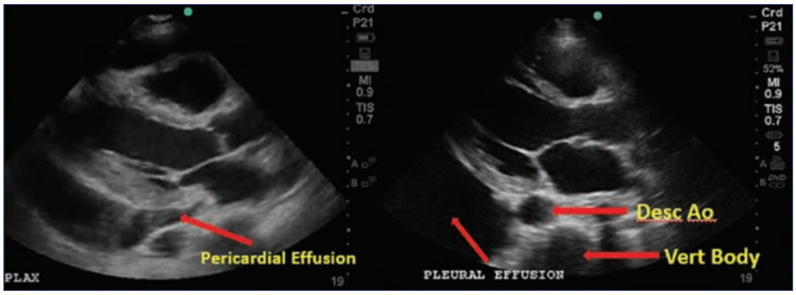
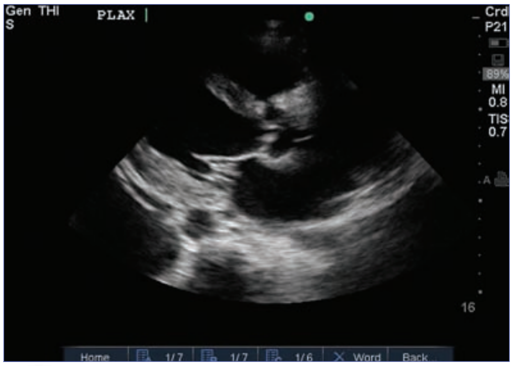


FIGURE 11.35 Pericardial versus pleural effusion.

Source: Courtesy of Thomas Costantino.

- Pleural effusions do not and will accumulate posterolaterally to the descending aorta.
- Typically, effusions identified in the subcostal view will be pericardial given there is no pleural reflection between the heart and liver.
- Effusions posterolateral to the heart in the subxiphoid view are typically pleural, whereas fluid between the liver and diaphragm is ascites.
- Look for the falciform ligament (**see VIDEO 11.20**) attached to the diaphragm and utilize multiple lung and abdominal views to help distinguish between these pathologic entities.
- To help identify a pleural effusion, lung consolidation or collapsed lung from atelectasis may be seen as well (**VIDEOS 11.17–11.20**).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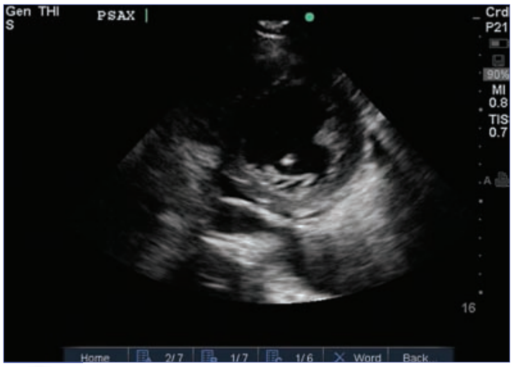
VIDEO 11.17 PSLA pleural effusion seen posterolateral to the heart small pericardial effusion.

PSLA, parasternal long axis.

Source: Courtesy of Thomas Costantino.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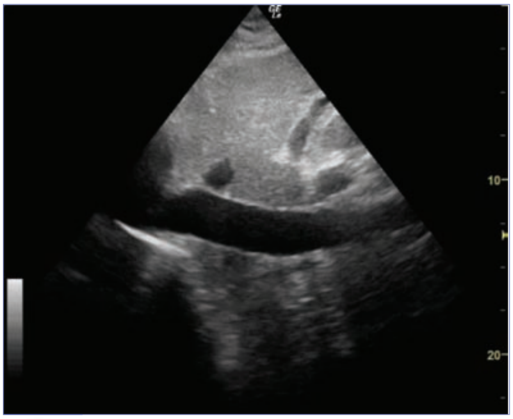
VIDEO 11.18 PSSA with pleural effusion posterolateral to heart small pericardial effusion.

PSSA, parasternal short axis.

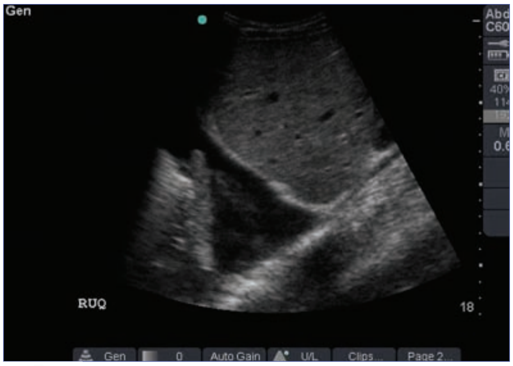
Source: Courtesy of Thomas Costantino.



VIDEO 11.19 PSLA pleural effusion with lung consolidation small pericardial effusion.

PSLA, parasternal long axis.

Source: Courtesy of Thomas Costantino.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VIDEO 11.20 Pleural effusion with lung collapse spine sign in right hemithorax.

Source: Courtesy of Thomas Costantino.

COMPLICATIONS

- Hemothorax
- Pneumothorax
- Hepatic or splenic injury
- Gastric injury
- Cardiac puncture
- Pneumopericardium
- Pneumomediastinum
- Infection
- Dysrhythmia
- Neurovascular injury

PEARLS

- FOCUS findings in cardiac tamponade are challenging even for advanced practitioners (**TABLE 11.12**).

TABLE 11.12 Cardiac Tamponade

False Positive	False Negative
Right-heart collapse* ■ Hypovolemia ⇨ Trauma ⇨ Dialysis	Lack of right-heart collapse** ■ Chronic cor pulmonale

*IVC collapse; therefore very unlikely tamponade.

**IVC plethora at baseline.

IVC, inferior vena cava.

- If the patient is hypotensive with an effusion, consider cardiac tamponade.
  - Consult cardiology immediately and prepare for an emergent pericardiocentesis.
  - Supplemental IV fluids can help augment CO as a temporizing measure.
  - Note even FOCUS is not 100% sensitive; any effusion with vascular instability may represent a tamponade and require treatment; treat the patient!
- If the patient is hemodynamically stable, defer pericardiocentesis to the cardiologist.
- Surgical evacuation is optimal for posterior, nonuniform (loculated or focal), complex, and thrombosed effusions.
- Traumatic effusions are best managed with surgical intervention as well, specifically a thoracotomy.
- Be cognizant of not overlooking large pericardial effusions because they are clotted; remember that clotted blood appears less anechoic than fresh blood.
- Without access to a cardiac catheterization lab or surgical specialties, an emergent pericardiocentesis can be a temporizing measure in the hemodynamically unstable.
- In the coding patient with an effusion, immediate pericardiocentesis is warranted; ideally with bedside ultrasound guidance as detailed here; it incorporates minimal equipment that every ED possesses (**FIGURES 11.36** and **11.37**).

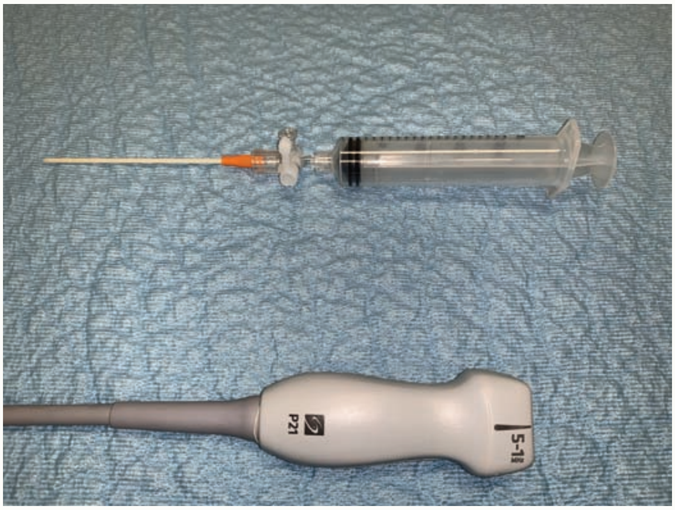

FIGURE 11.36 Minimal equipment is required for an emergent pericardiocentesis.

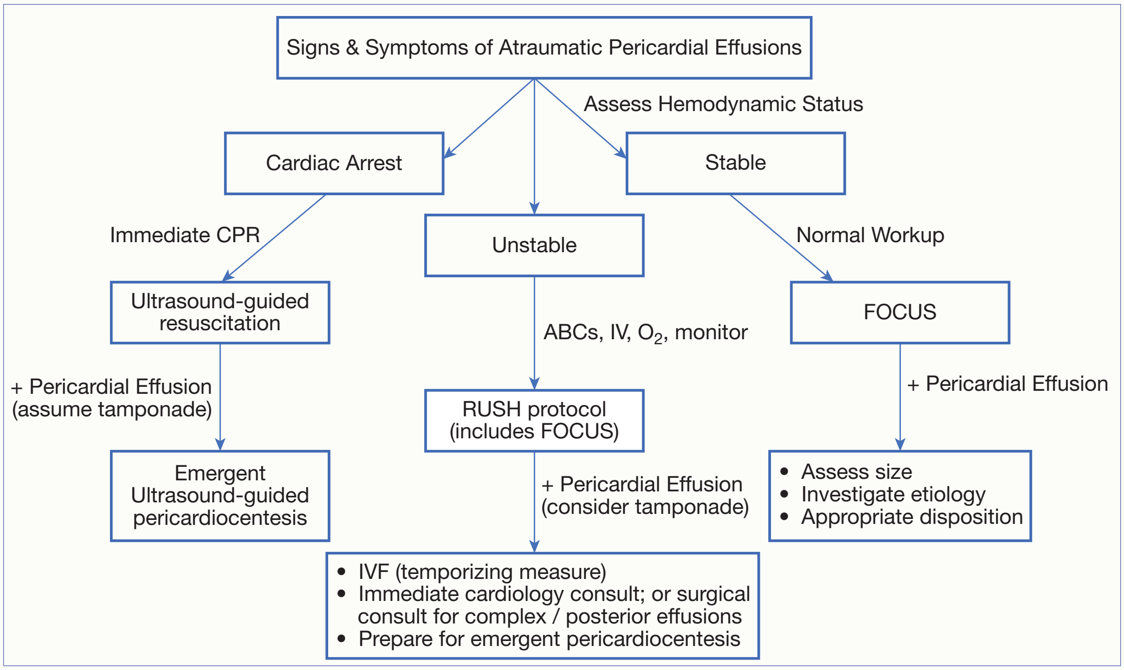
Signs & Symptoms of Atraumatic Pericardial Effusions
Assess Hemodynamic Status
Cardiac Arrest
Unstable
Stable
Immediate CPR
Normal Workup
Ultrasound-guided resuscitation
ABCs, IV, O_2, monitor
FOCUS
+ Pericardial Effusion (assume tamponade)
RUSH protocol (includes FOCUS)
+ Pericardial Effusion
Emergent Ultrasound-guided pericardiocentesis
+ Pericardial Effusion (consider tamponade)
• Assess size
• Investigate etiology
• Appropriate disposition
• IVF (temporizing measure)
• Immediate cardiology consult; or surgical consult for complex / posterior effusions
• Prepare for emergent pericardiocentesis

FIGURE 11.37 Diagnostic algorithm for atraumatic pericardial effusions.

ABC, airway, breathing, circulation; FOCUS, focused cardiac ultrasound; IVD, in vitro fertilization; RUSH, rapid ultrasound for shock and hypertension.

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UNIT
V

Intravenous Access

CHAPTER

12

Ultrasound-Guided Peripheral Venous Access

James Murrett and Thomas Constantino

BACKGROUND

Achieving intravenous (IV) access on patients is necessary for many laboratory diagnostics, medication administration, and resuscitation. In patients with a history of obesity, IV drug abuse, or frequent venous access in medical settings, it can be challenging to achieve IV access and may require ultrasound guidance. Furthermore, clinicians will often need a reliable method to get access in a rapid manner for patients who are severely hypovolemic or hypotensive.

Ultrasound-guided peripheral intravenous access (USGPIV) offers greater success with fewer attempts and better patient satisfaction. ***Studies place the success rate of ultrasound IV placement over 90% with higher success in comparison to the landmark approach with a success rate around 80%***. In addition, learning the skill of USGPIV can reduce the need for central venous access, enhancing patient comfort and safety. ***Au et al. (2012) have shown that using USGPIV has decreased the need for central-line placement by 85%***. Studies have shown it decreased time to achieve IV access by over 50% when USGPIV is used. USGPIV is an important skill set for all clinicians in the emergency setting.

Vascular Anatomy

Typical upper extremity veins are shown in **FIGURE 12.1**.

- The median antecubital vein is very superficial and is also short-running before it branches.
- The cephalic vein is a branch of the median antecubital and runs in the soft tissue proximal to the biceps. The distal portion near the radial aspect of the wrist has the nickname "intern's vein."
- The basilic vein is very medial but sometimes quite deep. It usually doesn't merge with the brachial veins until the axilla.
- The paired brachial veins run on either side of the brachial artery and posterior to the median nerve. Both of these structures should be avoided when cannulating the brachial veins.

Starting more distally will preserve the proximal veins for future attempts but may not maximize first-attempt success. We have anecdotally found that in obese patients, the median antecubital, basilic, and sometimes forearm veins are the best choices for USGPIV. In patients with chronic medical conditions or a history of IV drug use, the basilic and brachial veins are usually preferred. The saphenous vein near the ankle and chest wall veins can occasionally be used as well when arm veins are not suitable.

In general, the shallowest and largest vein that runs straight is the best choice for USGPIV. Often, longer angiocatheters are best for USGPIV, while still using the catheter-over-needle approach of peripheral venous access. Although midline and peripherally inserted central lines can be used, they utilize a Seldinger technique and are not discussed in this chapter.

When choosing a vein to calculate, some simple algebra can help. The angle of approach used with the needle can be adjusted based on the depth of the vein. However, ***with the needle at 45 degrees to the skin, the depth of the vessel***

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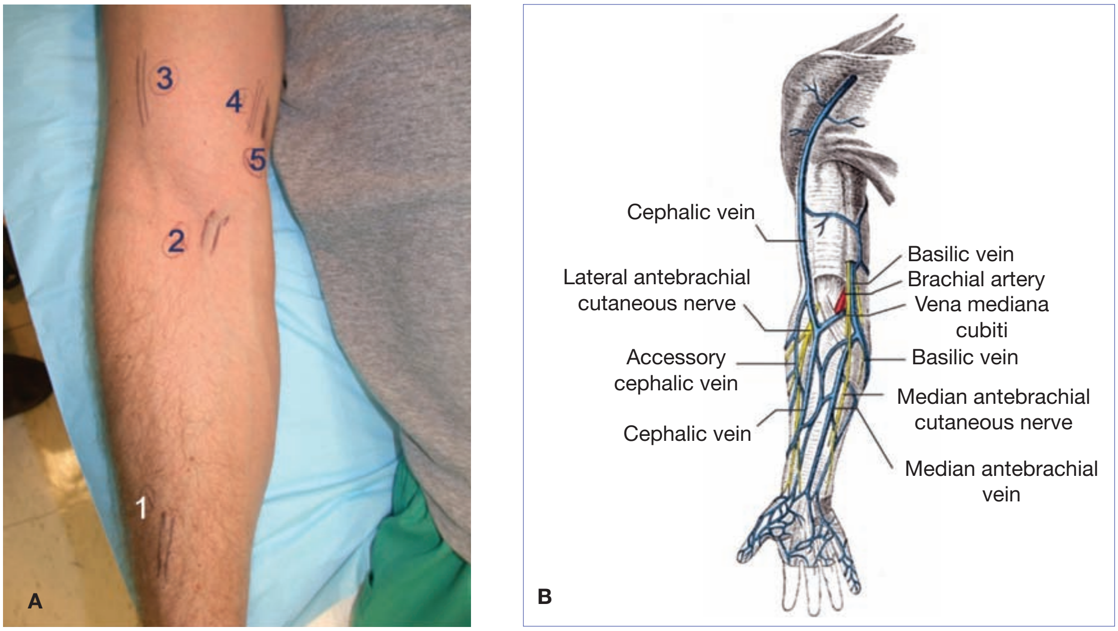
3
4
5
2
1
A
B
Cephalic vein
Lateral antebrachial cutaneous nerve
Accessory cephalic vein
Cephalic vein
Basilic vein
Brachial artery
Vena mediana cubiti
Basilic vein
Median antebrachial cutaneous nerve
Median antebrachial vein

FIGURE 12.1 (A): Common sites to look for veins: "Intern's vein" (distal portion of cephalic vein) (1), median antecubital vein (2), cephalic vein (3), brachial vein (4), basilic vein (5). (B): Vascular anatomy of upper extremity.

Source: (B): Gray, H. (1918). *Anatomy of the Human Body*. Lea and Febiger.

should match the distance from the probe to the entry point into the skin (**FIGURE 12.2**). For example, for a vessel 1-cm deep, entering the skin at 45 degrees 1 cm in front of the probe should allow for the needle tip to appear at the anterior wall of the vein without moving your probe.

Approaching a 2-cm deep vein at 45 degrees would require 2.8 cm—2 cm/sin(45)—of needle to reach the vein. For a typical 2.5-inch angiocatheter (6.35 cm), this would leave 3.5 cm of catheter in the vein. Of note, this is about the length (slightly longer) of a standard 1.25-inch IV (3.175 cm), which perhaps speaks to why ultrasound IVs have been shown to last longer than standard IVs. Therefore, it is best to attempt to cannulate veins with a depth of less than 2 cm if using a typical 2.5-inch angiocatheter. Veins less than 2 cm in depth would leave even more of the catheter in the vein, which should lead to less chance of catheter displacement with patient movement.

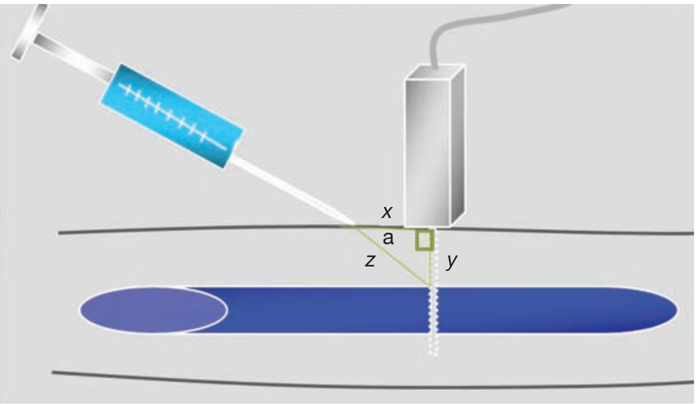

FIGURE 12.2 (Theorem) Because $x^2 + y^2 = z^2$, where x = standoff distance, y = depth of vein, z = length of needle penetration, and *a* = angle of approach, if you approach at a 45-degree angle, starting away from the probe the same distance as the vein is deep, the needle tip will arrive at the anterior wall of the vein exactly where your probe is located.

INDICATIONS

- *All the indications for IV access or blood sampling*
- *History of difficult IV access due to*
    - *Obesity*
    - *IV drug use*
    - *Chronic medical condition*
    - *Previous vascular surgeries in the upper extremity*

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Restrictions on access locations, excluding certain extremities because of dialysis access, indwelling central access, or history of malignancy, limit possibilities.
    - Recent literature questions the significance of this.
        - Winge, Mattiasson and Schultz (2010) question the validity of such dogma.
        - ***In a recent prospective study done at Harvard, Ferguson et al. (2016) looked at 632 mastectomy patients with invasive breast cancer over a period of 5 years and did not show any link between IV placement or blood pressure cuff placement and lymphedema.***
- Ask the patient whether they have any restrictions on extremities to use for access; many hospitals now use limb-restriction warning bands.
- Thrombus in vein
- Infection in the area overlying the vein
- Sites of prior access attempts (relative)
- Coagulopathy (relative)

PROCEDURE PREPARATION

This procedure should be performed using standard sterile precautions as with any IV insertion. The high-resolution linear probe allows for clear visualization of venous and other structures near the surface. Rectangular scanning demonstrates an image with beams remaining the full distance apart throughout the ultrasound image. National organizations allow the use of sterile gel and single-use protective covers for USGPIV followed by low-level disinfection.

Equipment

- Gloves
- Ultrasound machine with linear probe (**FIGURE 12.3**)
- Transparent film dressing or other probe cover (**FIGURE 12.4**)
- Ultrasound gel
- Sterile ultrasound gel
- Cleaning scrub/wipe such as chlorhexidine
- Tourniquet
- 2.5" long-catheter 18G IV

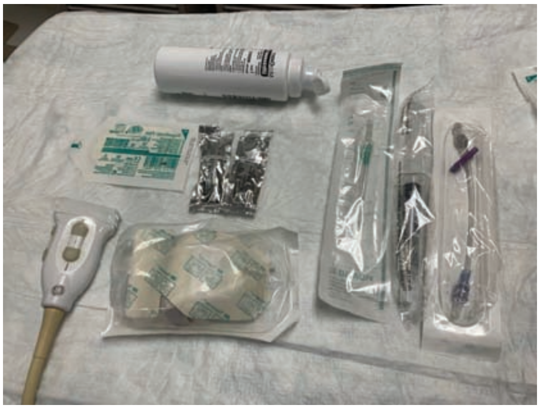

FIGURE 12.3 Equipment required for ultrasound IV: Ultrasound probe/machine, transparent film dressing or other probe cover, ultrasound gel, sterile ultrasound gel, IV kit (with IV film dressing, cleaning scrub/wipe, and tourniquet), 2.5-inch-long catheter 18G IV, saline flush, and IV tubing.

IV, intravenous.

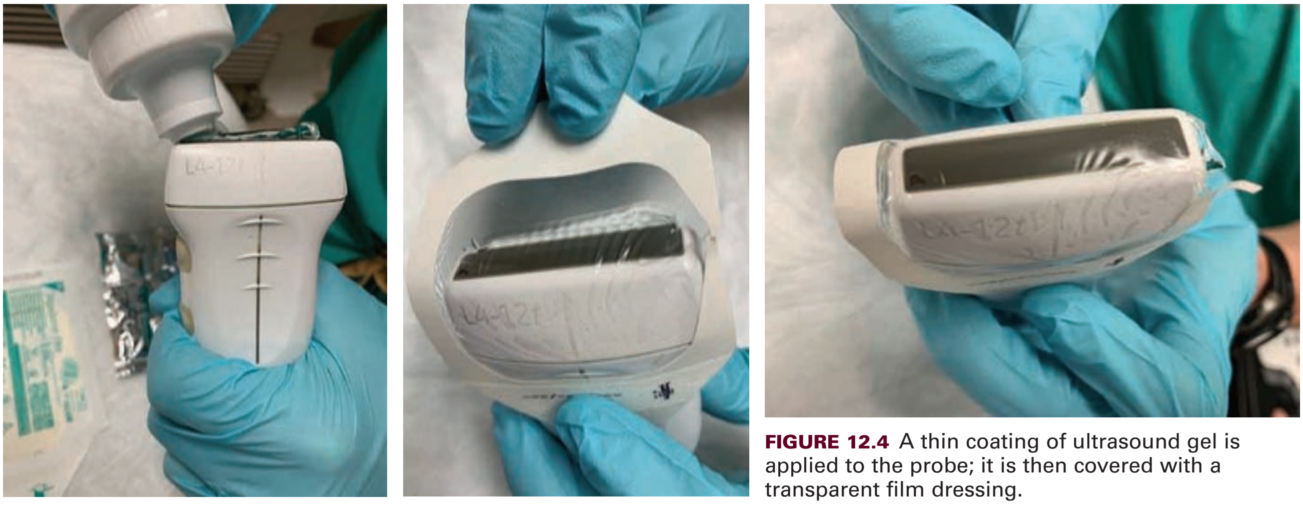

FIGURE 12.4 A thin coating of ultrasound gel is applied to the probe; it is then covered with a transparent film dressing.

- Saline flush
- IV tubing
- Mayo stand (**FIGURE 12.5**)

Considerations for Location

- In addition to the thinner wall appearance of veins, compression can help differentiate between arteries and veins. Arteries will have pulsatile flow while venous structures should allow for full compression. Doppler and color flow may also be useful for differentiation in difficult patients.
- Avoid proximity to nerves and arteries when possible. Although many veins neighbor on arteries, it would be best to avoid veins located under or above arteries.
- Larger veins that course in straight lines and slowly increase in depth are often easiest for access.

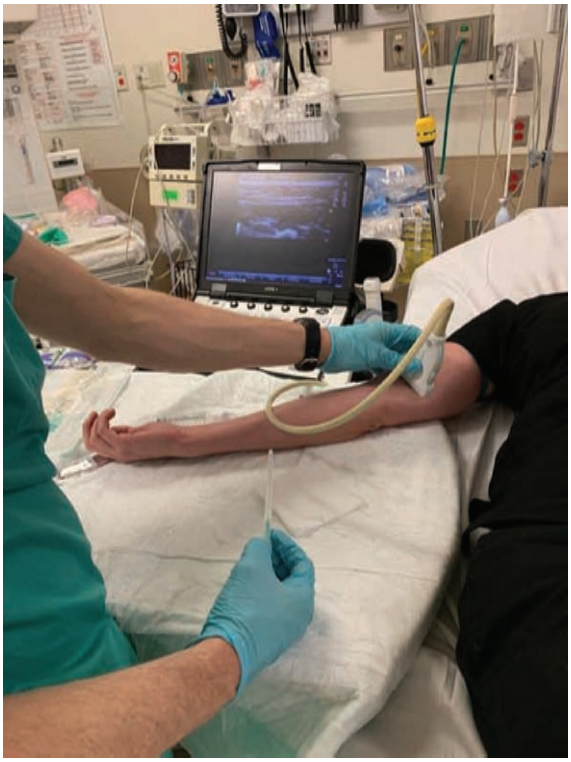

FIGURE 12.5 The use of a procedure table can allow the patient to fully extend their arm. Ultrasound machine is located behind the procedure table in the clinician’s line of sight.

PROCEDURE

Users can consider a transverse or longitudinal view of vessels for venous access. A transverse view allows for a cross-sectional view of vessels with easier spatial relationships. It can be more difficult to locate the needle using the longitudinal view, but it provides more information. While using the longitudinal view, it can be challenging for clinicians to keep the needle in plane and may require fanning and adjustment of the probe angle. In order to assist with this, some probes come with needle guides to keep the needle in plane with the probe view (**FIGURE 12.6**).

Transverse Approach (**FIGURE 12.7, VIDEO 12.1**)

- For upper extremity access, position patient supine (with head-of-bed elevated) with the arm abducted and supinated with full extension of the elbow.
- Place band tourniquet proximal on extremity to allow better visualization and catheterization of vessels. Tightness should be set to allow for venous filling but without leading to patient discomfort.

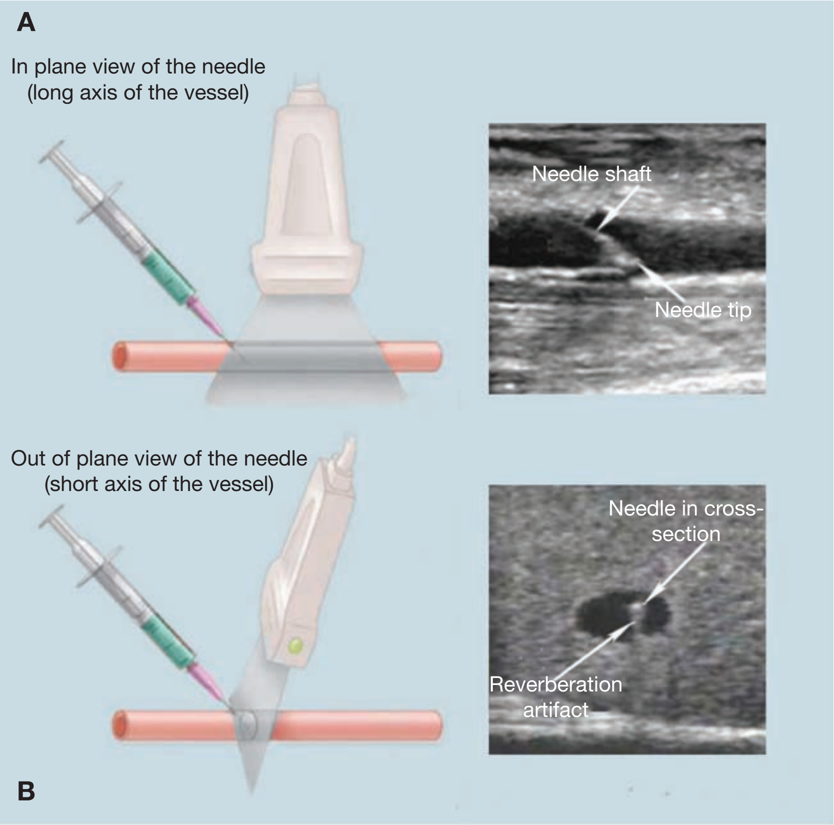
A
In plane view of the needle
(long axis of the vessel)
Needle shaft
Needle tip
Out of plane view of the needle
(short axis of the vessel)
Needle in cross-section
Reverberation artifact
B

FIGURE 12.6 Planes of ultrasound visualization for vascular access procedures. Panel (A) shows a long-axis, “in-plane” view of the needle. Although it may be more difficult to keep the needle and structure of interest in view, the long-axis view is advantageous because it shows the entire needle, including the distal end. Panel (B) shows a short-axis approach, with the center of the needle in the vessel lumen. Although the visualized portion of the needle is localized in the lumen, the shortcoming of the short axis is that the plane of the ultrasound may underestimate the depth of the needle tip.

Source: Reproduced with permission from American Institute of Ultrasound in Medicine. (2019). AIUM practice parameter for the use of ultrasound to guide vascular access procedures. (2019). *Journal of Ultrasound in Medicine, 38*, E4–E18. https://doi.org/10.1002/jum.14954

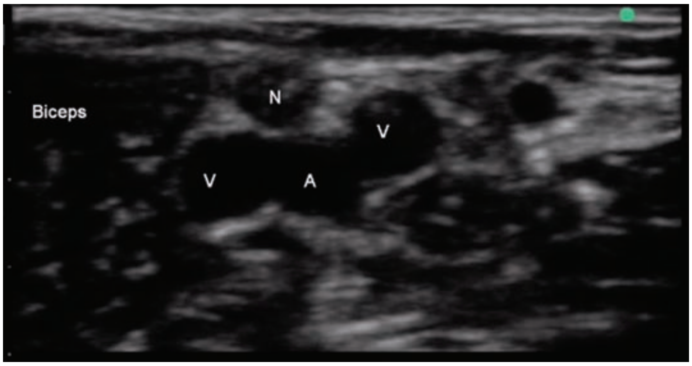

FIGURE 12.7 Transverse approach. The biceps is lateral. The paired brachial veins (V) are on either side of the brachial artery (A), which is below the median nerve (N). The most medial vein would be the ideal choice for vascular access as it would avoid the biceps and median nerve.

- Use the ultrasound probe to locate vein.
- Line up center of vein under middle of probe. Most probes will have a center marker (usually a line) that will show best location for IV insertion into the skin.
- Sweep along the vein to know the course. Knowing the course of the vein, line the probe orthogonal to the path of the vein so that sweeping will follow the vein.
- Use sterile gel on the skin after it has been cleaned appropriately with a chlorohexidine sponge, alcohol wipe, iodine, or other method.
- Insert the needle and locate it just under the skin with the ultrasound probe. The needle is dense and will appear bright on the ultrasound, likely with a reverberation artifact. It may sometimes be useful to "bounce" or move the needle slightly to identify its location.
- Sweep the transducer to identify the needle tip (where the reverberation artifact ends).
- Adjust angle as needed, then slowly advance the needle and sweep to reacquire the needle tip. This technique is known as "walking the needle tip forward."
- Advance the needle slowly toward the vessel and look for a flash of blood. After entering the vessel, the needle may not get a flash until the vessel reexpands.
- The needle should continue to be advanced at least 1 cm while remaining in the center of the vessel. Advance the catheter slowly, ensuring blood return.
- After drawing labs and connecting to IV tubing, be sure to remove the band tourniquet from the patient's extremity.

VIDEO 12.1 Transverse approach.

Longitudinal Approach

- For upper extremity access, position patient supine (with head-of-bed elevated) with the arm abducted and supinated with full extension of the elbow.
- Place band tourniquet proximal on extremity to allow better visualization and catheterization of vessels. Tightness should be set to allow for venous filling but without leading to patient discomfort.
- Use the ultrasound probe to locate the vein in the longitudinal view (**FIGURE 12.8**).
- Sweep and fan the probe to view the vein. Knowing the course of the vein, line the probe along the path of the vein so that the vein is fully visualized on the ultrasound.

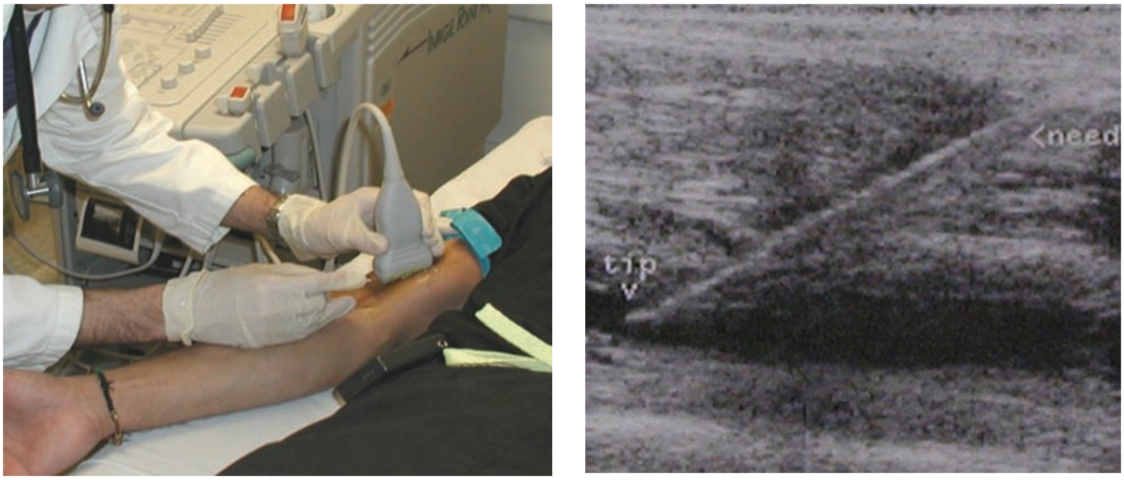

FIGURE 12.8 Ultrasound probe placement for longitudinal approach. Needle is kept in plane while achieving venous access.

- Use sterile gel on the skin after it has been cleaned appropriately with a chlorohexidine sponge, alcohol wipe, iodine, or other method.
- Insert the needle and locate it just under the skin with the ultrasound probe. The needle is dense and will appear bright on the ultrasound, likely with a reverberation artifact. It may sometimes be useful to “bounce” or move the needle slightly to identify its location.
- Keeping the needle in plane with the probe, slowly advance the needle toward the vein keeping the needle in view. The width of a typical needle is about 1 mm, as is the width of an ultrasound beam. Keeping both objects in plane as well as the vein can be challenging.
- Advance the needle slowly toward the vessel and look for a flash of blood. After entering the vessel, the needle may not get this flash until the vessel reexpands.
- Lowering the angle of approach, the needle should continue to be advanced at least 1 centimeter while remaining in the center of the vessel. Advance the catheter slowly, ensuring blood return.
- After drawing labs and connecting to IV tubing, be sure to remove the band tourniquet from the patient’s extremity.

Two-Person Method

- An assistant can manage the transducer while the operator places the catheter, although this requires good communication and is not often needed.

POSTPROCEDURE CONSIDERATIONS

- IV site should be monitored for infiltration
- Infection

EDUCATIONAL POINTS

- USGPIV offers greater success and reduces the need for more invasive procedures.
- The ideal vessel is easily compressible, thin walled, nonpulsatile, and not proximal to a neighboring artery or nerve. Color-flow doppler can also be used to differentiate an artery from a vein.
- Using a longer, 2.5-inch angiocatheter allows more reliable access to deeper structures. Veins located less than 2-cm deep are easier to cannulate.
- Identification of a relatively straight vein that slowly increases in depth can increase success.

PEARLS

- Although standard peripheral IV catheters can be used, the longer 2.5-inch 18G angiocatheters are more useful to access deeper veins.
- Should the vessel tent (wrap around the needle), there are two approaches to achieve access. Some clinicians find success going to the posterior wall of the vessel and then pulling back, allowing the needle to enter the vessel. However, by continuing to follow the vessel and keep the needle centered in the vein, the needle will eventually enter the vessel.
- It is best for beginners to attempt to cannulate veins with a depth of less than 2 cm.
- Starting away from the probe the same distance as the vein is deep allows the needle tip to arrive at the anterior wall of the vein exactly where your probe is located.
- Ultrasound monitor must be in the clinician’s line of sight during the procedure.
- Unless the vein is easily palpated, one should use the USGPIV method of venous cannulation as the days of aimlessly and perpetually sticking a patient should be a thing of the past.
- ***Using USGPIV decreases the need for central-line placement by 85%.***
- In patients with chronic medical conditions or a history of IV drug use, the basilic and brachial veins are usually preferred.
- In general, the shallowest and largest vein that runs straight is the best choice for USGPIV.
- If you approach at a 45-degree angle, starting away from the probe the same distance as the vein is deep, the needle tip will arrive at the anterior wall of the vein exactly where your probe is located.

RESOURCES

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CHAPTER 13

Intraosseous Access and Infusion

Ryan P. Bierle

BACKGROUND

Clinicians commonly face frustration when working to gain vascular access during emergency situations. Frequently, traditional attempts to establish peripheral intravenous access are complicated by the decreased venous flow seen in patients with shock or cardiac arrest. Consequently, clinicians are often compelled to access larger veins through blind or ultrasound-guided central venous catheterization, a procedure that carries a significant risk of serious complications and is time-consuming. Intraosseous (IO) infusions offer a safe and rapid alternative method of vascular access during emergent resuscitations, with first-pass success rates as high as 97% in less than a minute (Fenwick, 2010).

As early as 1922, the concept of utilizing the IO space for vascular access and infusion was first proposed, with the marrow being described as a "noncollapsible vein" (Drinker, Drinker, & Lund, 1922). The medullary sinuses of the long bones drain into veins that return to the central circulation. These veins remain patent during shock due to the support from the bony matrix. Please see **FIGURES 13.1** and **13.2** for images of the bone anatomy and matrix. Initially, IO infusions were reserved for infants and children. Increasingly, the technique is being utilized in adult patients presenting with medical or traumatic shock. IO infusion for emergent vascular access across the life span is now recommended and taught during numerous training programs, including Advanced Cardiac Life Support (ACLS), Advanced Trauma Life Support (ATLS), Pediatric Advanced Life Support (PALS), and Tactical Combat Casualty Care (TCCC; Garside, Prescott, & Shaw, 2016; Petitpas et al., 2016).

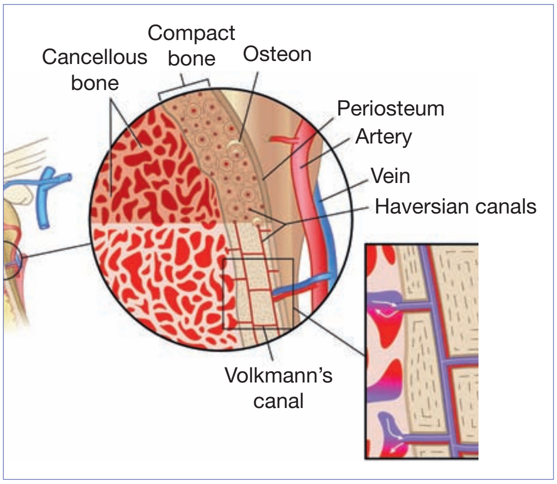

FIGURE 13.1 Intraosseous anatomy.

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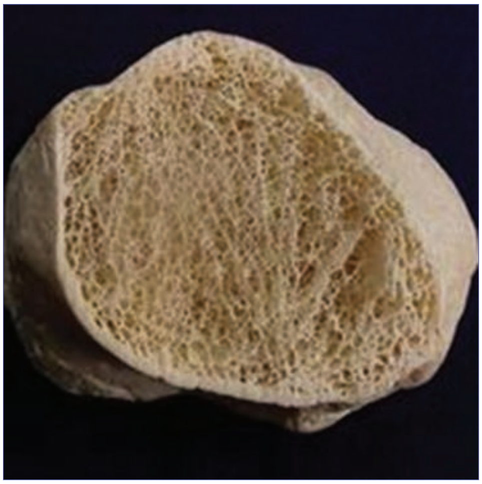

FIGURE 13.2 Intraosseous bony matrix.

Source: Courtesy of Scotty Bolleter.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

PATIENT PRESENTATION

IO access is indicated in patients who are unlikely to have traditional vascular access initiated in a safe or timely manner. Although the most typical indication is seen during cardiac arrest and cardiopulmonary resuscitation (Petitpas et al., 2016), additional indications may include the following:

- Any hemodynamically unstable patient (e.g., multisystem trauma or shock)
- Situations in which the medical condition precludes conventional intravenous access for the safety of the patient and healthcare workers (e.g., excited delirium, status epilepticus, confined space rescue)
- Patients in whom traditional intravenous access is unlikely to be successful in a timely manner (e.g., pediatric and neonatal patients, patients with contractures, chronically ill patients with a history of repeated vascular access, and patients with a history of intravenous drug abuse)

TREATMENT

Once the clinician has identified an appropriate patient, they must ensure that the patient has no contraindications to the placement of an IO needle. Next, the clinician must select a proper insertion site, which is dependent upon device availability and the patient's anatomical considerations. Because clinical practice sites may offer different devices, it cannot be overemphasized that it is the best practice for the clinician to be familiar with the available supplies ***prior*** to use in an emergent situation.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Contraindications include excessive tissue (severe obesity) and/or absence of anatomical landmarks as well as previous significant orthopedic procedure at the site or prosthetic limb or joint.

In general, the clinician should avoid the following insertion sites:

- Areas with disruption of the circulatory system feeding the selected long bone; if a disruption exists (such as a bone fracture, previous failed IO attempt in the same bone, or distal amputation at the selected site), the infused medications or intravenous fluids will exit through the defect rather than enter the systemic circulations
- Overlying burns or cellulitis or underlying osteomyelitis
- Excessive tissue (severe obesity) and/or absence of adequate anatomical landmarks
- Previous, significant orthopedic procedure at the site, prosthetic limb or joint

SPECIAL CONSIDERATIONS

- Clinicians often are hesitant to place an IO needle out of concern for causing pain to the patient. However, patients rate IO needle insertion as less painful than other standard emergent procedures, including placement of urinary catheters, nasogastric tubes, arterial catheters, and central venous catheters. **FIGURE 13.3** demonstrates the two receptors encountered during IO insertion. Patients do report high pain scores during rapid or high-volume fluid administration, but this can be mitigated through pretreatment with 2% preservative-free intravenous lidocaine without epinephrine in an initial typical adult dose of 40 mg (2 mL). Slowly infuse the 2 mL (40 mg) over 120 seconds and allow it to dwell for 60 seconds. Carefully detach the lidocaine syringe and attach a syringe containing 5 to 10 mL of normal saline, and flush over 5 seconds. The rapid flush is necessary to establish a free-flowing outlet for the infusion and is usually reported as the most painful part of the procedure. Following the normal saline flush, an additional half dose (20 mg or 1 mL) of 2% preservative-free intravenous lidocaine without epinephrine is slowly pushed over 60 seconds. Completion of this medication regimen before pressure infusions of large volumes of intravenous fluids significantly reduces reported pain scores (Philbeck, Miller, Montez, & Puga, 2010).

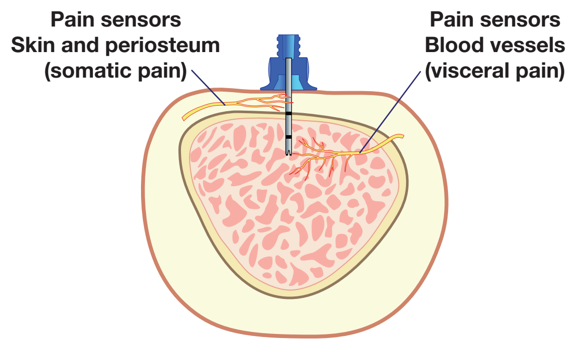

FIGURE 13.3 Intraosseous pain receptors.

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- Conditions associated with increased fragility of the skeletal system, such as osteoporosis or osteogenesis imperfecta, must be considered (Petitpas et al., 2016).
- Pain management for the procedure:
  - It should be noted that IO access is usually reserved for use in patients who are gravely ill and in whom the benefits of rapid intravascular access outweigh the risk of inflicting pain. Pain during rapid or high-volume fluid administration can be mitigated through pretreatment with 2% preservative-free intravenous lidocaine without epinephrine.

PROCEDURE PREPARATION

- Chlorhexidine, povidone-iodine, or other antiseptic
- Personal protective equipment (PPE), gloves, barrier devices
- Saline flush with extension tubing
- Padding or commercial stabilization devices
- 2% preservative-free intravenous lidocaine without epinephrine (in responsive patients)
- IO needle (**FIGURE 13.4**)
  - Manual IO Jamshidi needles (**FIGURE 13.5**)
  - Impact devices: Bone injection gun (BIG), FAST1 (**FIGURE 13.6**)
  - Battery driver: EZ-IO (**FIGURE 13.7**)

PROCEDURE

- For all devices and insertion sites:
  - Check for contraindications.
  - Gather supplies.
  - Don personal protective equipment.
- Select appropriate site (**TABLE 13.1**, **FIGURES 13.8–13.12**, **VIDEOS 13.1–13.4**).
- Cleanse selected site as per institutional policy.

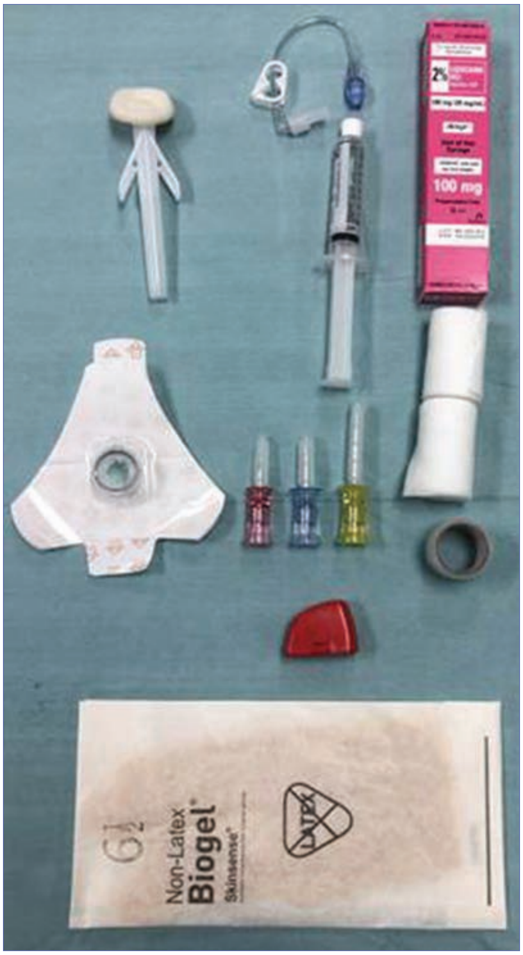

2%
100 mg
Non-Latex
Biogel
Skinsense
LATEX
6½

FIGURE 13.4 Intraosseous supplies.

Source: Courtesy of Ryan Bierle.

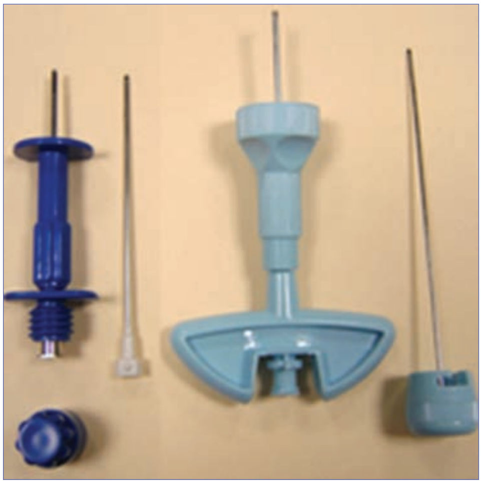


FIGURE 13.5 Manual intraosseous Jamshidi needles.

Source: Reproduced with permission from Medscape (https://emedicine.medscape.com).

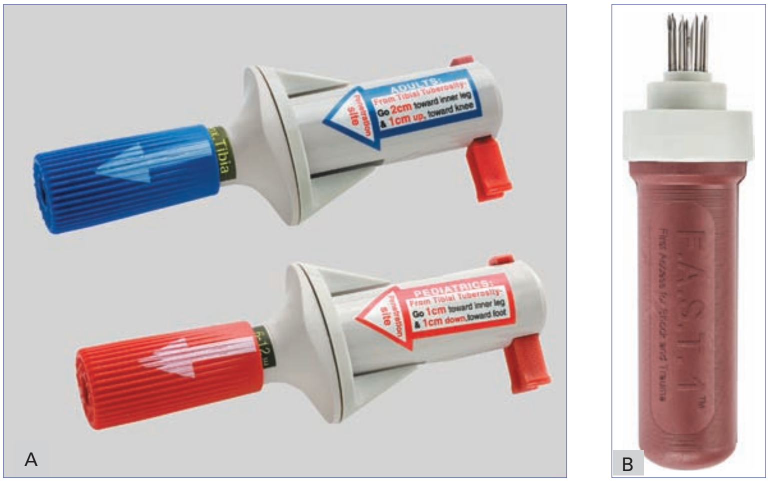

ADULTS
From Tibial Tuberosity:
Go 2cm toward inner leg
& 1cm up, toward knee
Penetration Site
Tibia
PEDIATRICS
From Tibial Tuberosity:
Go 1cm toward inner leg
& 1cm down, toward foot
Penetration Site
A
F.A.S.T.1
B

FIGURE 13.6 Impact devices: (A) Bone injection gun. (B) FAST1.

Sources: (A) Courtesy of Persysmedical and (B) image courtesy of Teleflex Incorporated. © 2021 Teleflex Incorporated. All rights reserved.

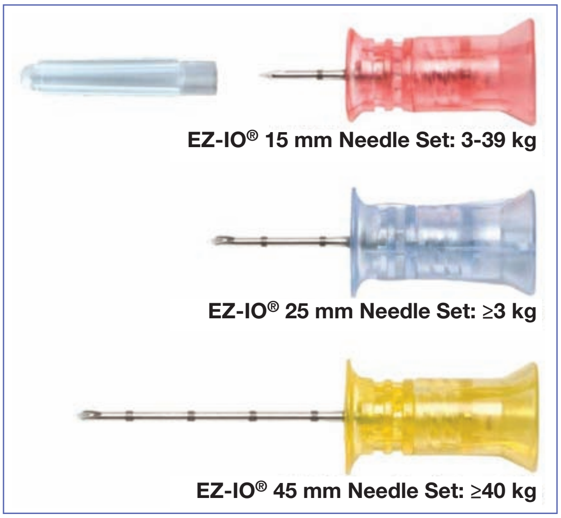
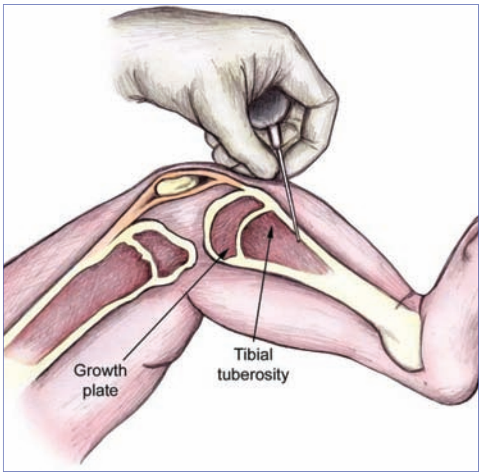

EZ-IO® 15 mm Needle Set: 3-39 kg
EZ-IO® 25 mm Needle Set: ≥3 kg
EZ-IO® 45 mm Needle Set: ≥40 kg

FIGURE 13.7 EZ-IO needles.

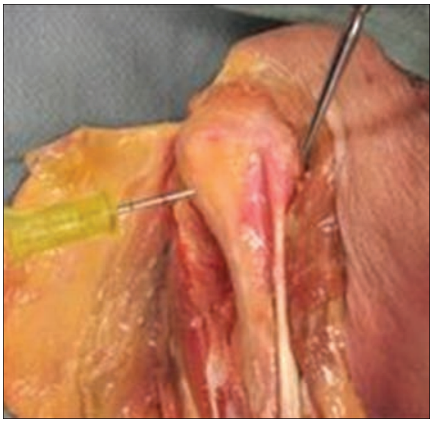
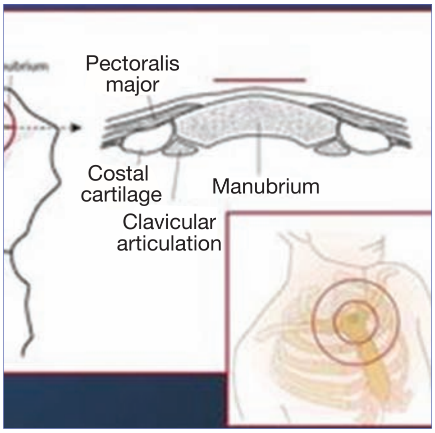
Source: Image courtesy of Teleflex Incorporated. © 2021 Teleflex Incorporated. All rights reserved.

TABLE 13.1 Insertion Sites

Site	Comments	Figure	Video (link)
Proximal tibia	■ Adult insertion site is approximately 3 cm below the patella and approximately 2 cm medial to the tibial tuberosity along the flat aspect of the tibia (depending on patient anatomy) ■ Neonate and young child insertion site is approximately 1 cm medial to the tibial tuberosity. If the tibial tuberosity cannot be palpated, the insertion site is approximately 1–2 cm below the patella and approximately 1 cm medial, along the flat aspect of the tibia (depending on patient anatomy) ■ Insertion site with the highest first-pass success rates ■ Appropriate for adult and pediatric patients ■ In responsive patients, high pain scores reported with large-volume infusions	 Growth plate Tibial tuberosity **FIGURE 13.8**	 **VIDEO 13.1** Proximal tibia EZ-IO insertion.

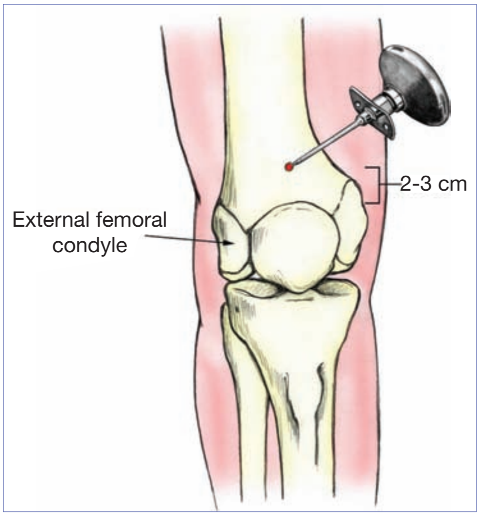
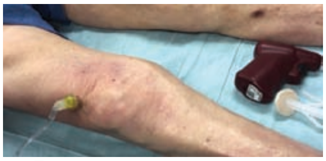
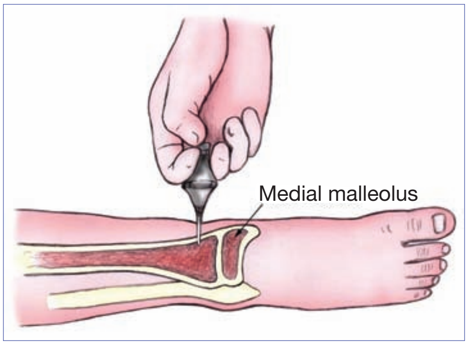
(*continued*)

TABLE 13.1 Insertion Sites (*continued*)

Site	Comments	Figure	Video (link)
Proximal humerus	■ 1 cm superior to the surgical neck of humerus, place arm in an adducted position with internal rotation (hand overlying the umbilicus), then locate the greater tubercle of the proximal humerus by palpating approximately 2 cm below the acromion process or palpating superiorly along the humerus ■ Anatomy and overlying soft tissue make landmark identification more difficult than other sites	 **FIGURE 13.9**	 **VIDEO 13.2** Proximal humerus EZ-IO insertion.
	■ Appropriate for adult and skeletally mature pediatric patients ■ Rapid infusion rates with studies showing infusions reaching central circulation at speeds similar to central venous catheters ■ Lower first-pass success rates when compared to the proximal tibia; also higher rates of needle dislodgement ■ Responsive patients report lower pain scores with high-volume infusions when compared to other insertion sites		
Sternum	■ In the body of the manubrium ■ Appropriate for adult patients ➢ Only accessible with the FAST1 intraosseous device and EZ-IO Talon devices ■ High flow rates reported; use is popular in military/tactical applications	 Pectoralis major Costal cartilage Manubrium Clavicular articulation **FIGURE 13.10**	

(*continued*)

TABLE 13.1 Insertion Sites (*continued*)

Site	Comments	Figure	Video (link)
Distal femur	■ 1–2 cm proximal to the superior border of the patella and approximately 1 cm medial to midline ■ Appropriate for pediatric patients (off-label use in adults) ■ Anatomy and overlying soft tissue make landmark identification more difficult than other sites	 **FIGURE 13.11**	 **VIDEO 13.3** Distal femur (Distal Femur EZ-IO insertion)
Distal tibia/ medial malleolus	■ 1–2 cm proximal to the medial malleolus ■ Appropriate for adult and pediatric patients ■ Less studied than other insertion sites, but remains a valid option, presumptively similar to the proximal tibia for subjective pain in responsive patients	 **FIGURE 13.12**	**VIDEO 13.4** Distal tibia/medial malleolus (medial malleoloar/ EZ-IO insertion)

Source: Figures 13.8, 13.11, 13.12 reproduced with permission from Medscape. Retrieved from https://emedicine.medscape.com/article/940993-overview

- Manual insertion:
  - Stabilize selected site.
  - Insert the needle through the skin and soft tissues at a 90-degree angle until needle tip reaches the periosteum (**FIGURE 13.13A** and **13.13B**).
  - While maintaining a 90-degree angle, apply steady pressure and twist or rotate clockwise and counterclockwise until the needle enters the marrow space; this is usually felt as a “pop” or “give” when resistance suddenly decreases.
  - Remove the inner stylet and dispose of in a sharps container (**FIGURE 13.13C**).
  - Attach primed extension tubing.
  - Aspirate bone marrow.
  - Flush (consider analgesia as described in the following text) and ensure there is no extravasation into adjacent soft tissues.
  - Secure with padding.
- **VIDEO 13.5** demonstrates use of multiple landmarks.
- EZ-IO:
  - Select appropriate-length needle (Pink 15 mm, Blue 25 mm, Yellow 45 mm) for patient’s weight/overlying depth of soft tissue, attach to the EZ-IO Power driver (magnetic; **FIGURE 13.14**).

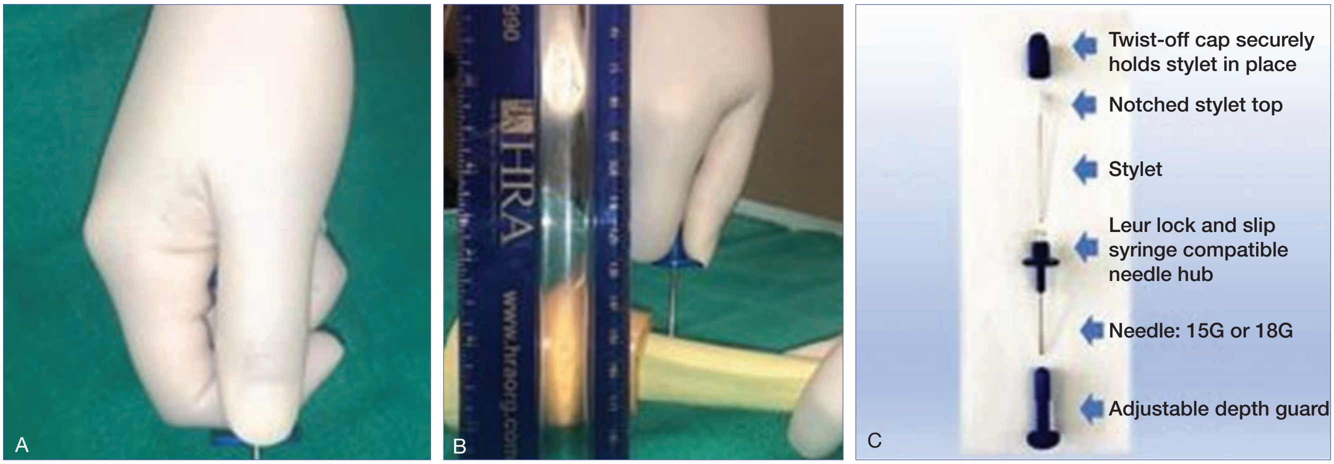

A
B
HIRA
www.hraorg.com
C
Twist-off cap securely holds stylet in place
Notched stylet top
Stylet
Leur lock and slip syringe compatible needle hub
Needle: 15G or 18G
Adjustable depth guard

FIGURE 13.13 Manual insertion of intraosseous needle.

Source: Courtesy of Scotty Bolleter.

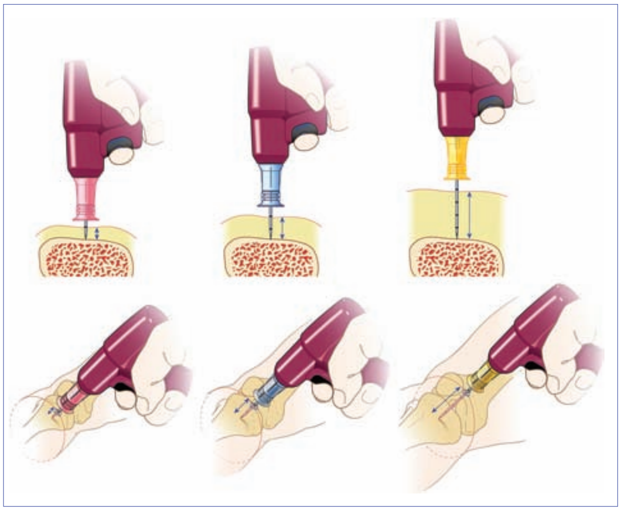
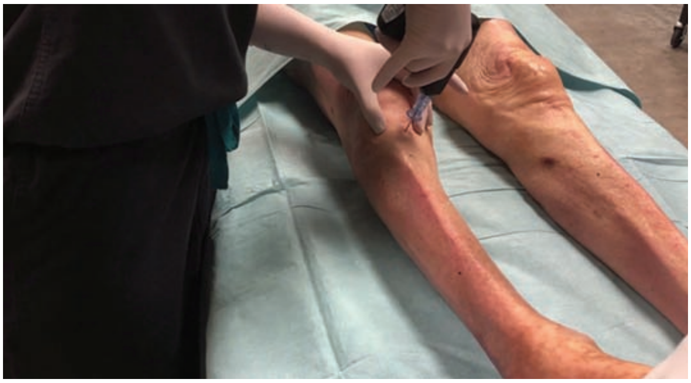


FIGURE 13.14 Appropriate length of needle.

Source: Image courtesy of Teleflex Incorporated. © 2021 Teleflex Incorporated. All rights reserved.



VIDEO 13.5 Multiple landmarks.

- Stabilize selected site.
- Remove safety cap from catheter.
- Insert the needle through the skin and soft tissues at a 90-degree angle (45-degree angle for proximal humerus insertions) until needle tip reaches the periosteum; ensure that the 5-mm black mark on the needle is still visible (ensures adequate needle length to reach the bone marrow; **FIGURE 13.15**).
- While maintaining a 90-degree angle, apply steady pressure and squeeze the driver trigger; when the needle enters the marrow space the change in resistance is noted by a difference in the pitch of noise from the power driver and a marked decrease in resistance.
- Remove the driver from the needle (pull straight back to disconnect the magnetic coupling), remove the inner stylet, and dispose of the stylet in a sharps container.
- Consider placing the commercially available EZ-Stabilizer dressing.
- Attach primed extension tubing.
- Aspirate bone marrow (**VIDEO 13.6**).
- Flush (consider analgesia as described in the following text) and ensure there is no extravasation into adjacent soft tissues.
- Secure with the available EZ-Stabilizer dressing or padding.

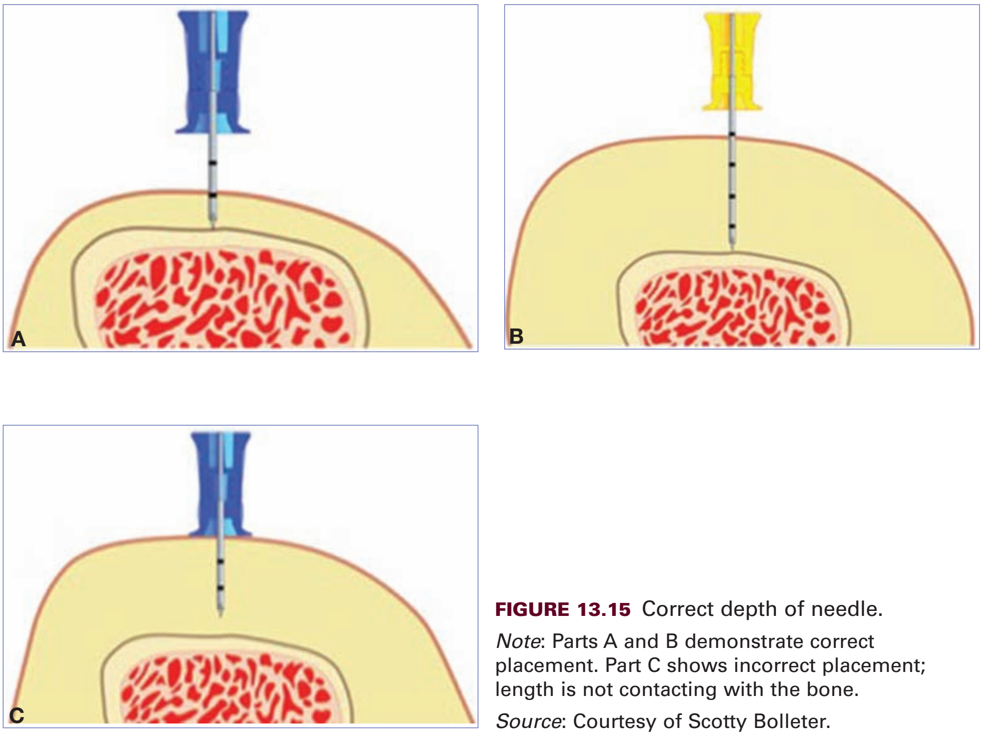
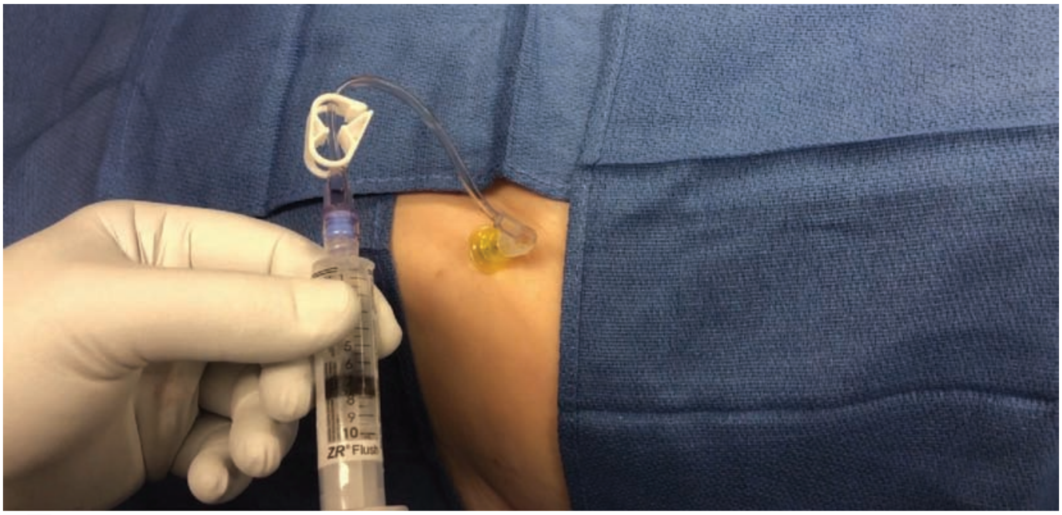


FIGURE 13.15 Correct depth of needle.

Note: Parts A and B demonstrate correct placement. Part C shows incorrect placement; length is not contacting with the bone.

Source: Courtesy of Scotty Bolleter.



VIDEO 13.6 Bone marrow aspiration.
Source: Courtesy of Scotty Bolleter.

- FAST1 device (**FIGURE 13.16**)
  - Identify the insertion site and apply the included target patch (**FIGURE 13.17A**).
  - Remove the sharps caps from the device.
  - Place the circular bone probe needles in the center of the target zone (**FIGURE 13.17B**).
  - While maintaining a 90-degree angle, apply steady pressure until a "pop" indicates the central IO needle has entered the bone marrow space.
  - Remove the device handle, and attach primed extension tubing.
  - Aspirate bone marrow.
  - Flush (consider analgesia as described in the text that follows) and ensure there is no extravasation into adjacent soft tissues.
  - Attach the included round plastic protector dome (**FIGURE 13.17C**).

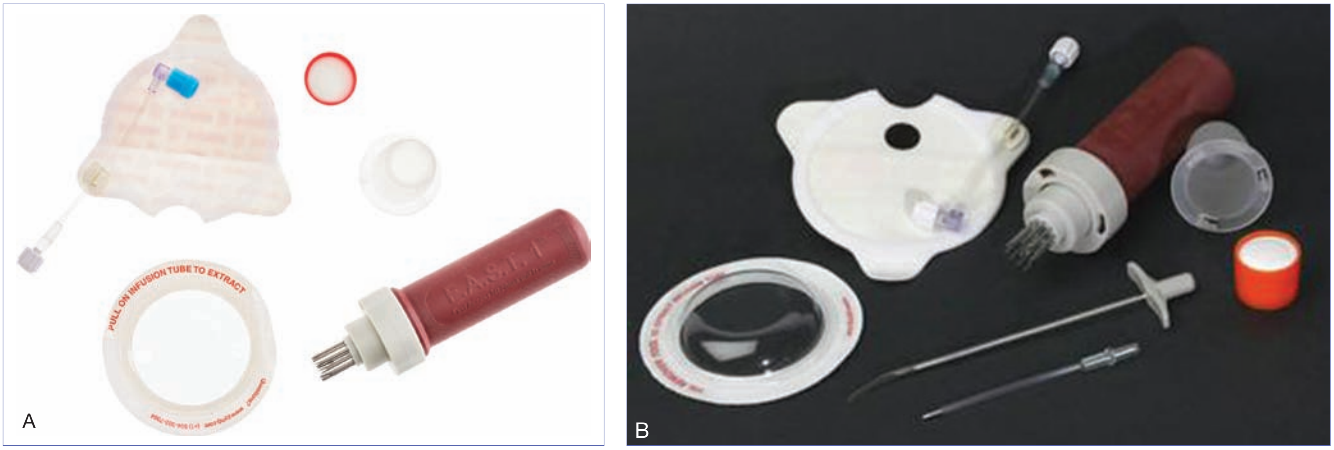


FIGURE 13.16 FAST1 device.

Sources: (A) Image courtesy of Teleflex Incorporated. © 2021 Teleflex Incorporated. All rights reserved. (B) Eslami, P. (2016). Pediatric intraosseous access. In R. K. Minkes (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/940993-overview. Reproduced with permission from Medscape.

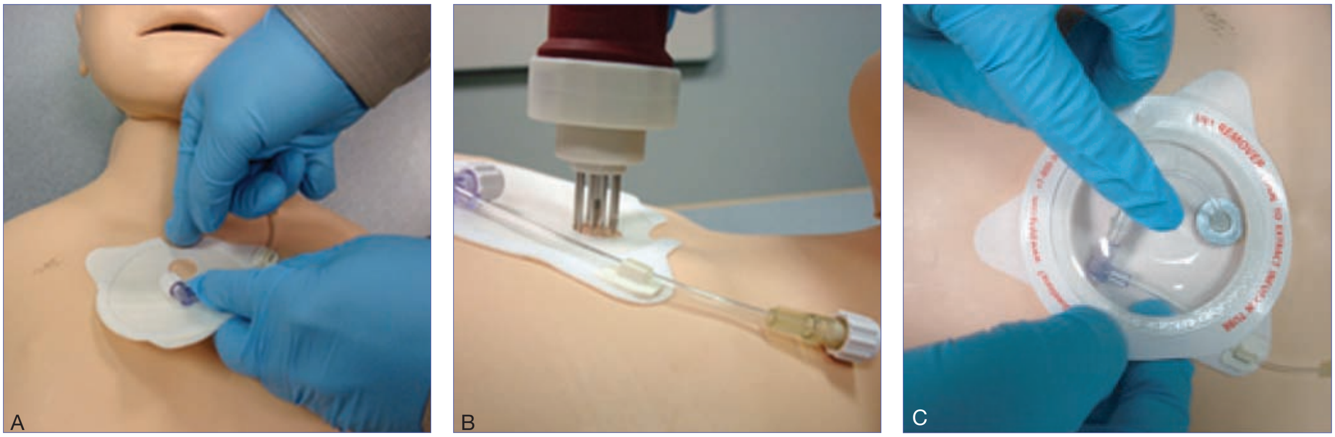


FIGURE 13.17 Insertion of FAST1 device. This device is approved for patients 12 years of age and older.

Source: Tay, E. T., and Hafeez, W. (2019). Intraosseous access. *Medscape*. https://reference.medscape.com/article/80431-overview. Reproduced with permission from Medscape.

- BIG device (**FIGURE 13.18**):
    - Identify the insertion site and place device at a 90-degree angle with the nondominant hand.
    - Squeeze and remove the orange safety latch from the device.
    - While maintaining a 90-degree angle by holding firmly with the nondominant hand, apply steady pressure and press the palm of the dominant hand on the device until a "pop" is heard. This indicates the central IO needle has deployed and entered the bone marrow space.
    - Remove the device by pulling upward.
    - Remove the inner stylet and dispose of in a sharps container.
    - Secure with the orange safety latch and tape.
    - Attach primed extension tubing and aspirate bone marrow.
    - Flush (consider analgesia as described in the text that follows) and ensure there is no extravasation into adjacent soft tissues.
    - Infuse pain medication and/or fluids.
    - For responsive patients, pain during rapid or high-volume fluid administration can be mitigated through pretreatment with 2% preservative-free intravenous lidocaine without epinephrine in an initial typical adult dose of 40 mg (2 mL). For pediatric patients, the dose is 0.5 mg/kg not to exceed the adult dose of 40 mg. Slowly infuse the initial dose over 120 seconds and allow it to dwell for 60 seconds. Carefully detach the lidocaine syringe and attach a syringe containing 5 to 10 mL of normal saline and flush over 5 seconds. The rapid flush is necessary to establish a free-flowing outlet for the infusion and is usually reported as the most painful part of the procedure. Following the normal saline flush, an additional half dose (20 mg for adults or half of the initial dose for children) of 2% preservative-free intravenous lidocaine without epinephrine is slowly pushed over 60 seconds. Pediatric patients have a repeat dose of half the initial dose (0.25 mg/kg) not to exceed the adult repeat dose of 20 mg. Completion of this medication regimen before pressure infusions of large volumes of intravenous fluids significantly reduces reported pain scores (Philbeck et al., 2010).

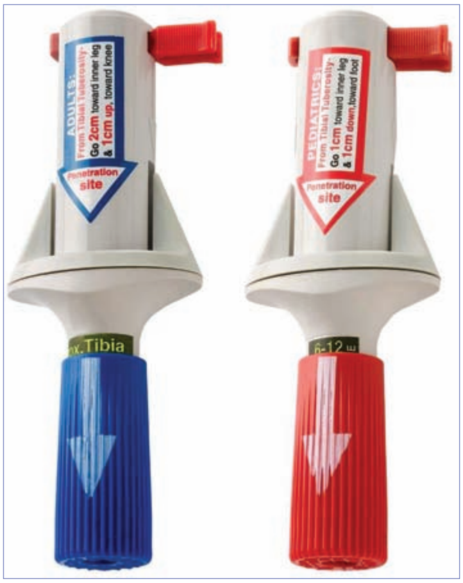


FIGURE 13.18 BIG device.

BIG, bone injection gun.

Source: Eslami, P. (2016). Pediatric intraosseous access. In R. K. Minkes (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/940993-overview. Reproduced with permission from Medscape.

POSTPROCEDURE CONSIDERATIONS

- Site care/dressing to be applied.
- Monitor the IO access site for signs of dislodgement and extravasation into the adjacent soft tissues. These complications can be mitigated by protecting the insertion site with commercially available securement devices or padding.
- Consider the early removal of IO access. Although IO needles may be left in place for up to 24 hours, complications and infections increase with prolonged access (Fenwick, 2010). IO access may often serve as a "bridge" until the patient's condition has improved, and traditional methods of intravenous access may be completed in a safe manner. Specific removal techniques are based on the insertion technique or device.
    - Manual insertion: Remove with steady firm traction at 90-degree angle and a twisting motion (similar to insertion).
    - EZ-IO: Remove the extension tubing and attach a Luer-Lok syringe. Use steady firm traction at 90-degree angle and a twisting motion to remove (**VIDEO 13.7**).
    - FAST1 device: Remove the extension tubing, then the orange safety latch, and seat the catheter hub in the square notch (a Luer-Lok syringe may also be utilized). Pull with steady firm traction at a 90-degree angle to remove.
    - BIG device: Remove the protective dome and extension tubing. Use steady firm traction at a 90-degree angle and a twisting motion to remove.
- Following removal of an IO, apply firm pressure; however, the site only requires standard wound dressings.

VIDEO 13.7 Intraosseous device removal.

Source: Courtesy of Scotty Bolleter.

EDUCATIONAL POINTS

- The use of prophylactic antibiotics is not needed.
- The proximal tibia offers the highest rate of first-pass success but is also associated with higher patient-reported pain scores and lower infusion rates.
- The proximal humerus offers infusion rates that rival central venous access and lower patient-reported pain scores, but is associated with a lower first-pass success rate and higher needle dislodgement rates than the proximal tibia.

COMPLICATIONS

- The most common clinical complications are the inability to adequately place the device in the marrow space and dislodgement of the needle.
- Osteomyelitis and IO abscess are rarely reported complications (Henson, Payan, & Terk, 2011), and their incidence is significantly reduced through the use of aseptic technique and ensuring the needle is not left in place longer than the recommended 24-hour period (Petitpas et al., 2016).
- Extravasation of infused fluids, whether from needle dislodgement or a “through and through” extension of the needle into the subcutaneous tissues on the opposite side of the targeted long bone, can result in a compartment syndrome. Extravasation has been most commonly described in the lower extremities, but there are reports of compartment syndrome occurring with humeral IO insertion (Thadikonda, Egro, Ma, & Spiess, 2017).

PEARLS

- IO access is indicated in critically ill patients with actual or predicted difficulty in accessing the peripheral vasculature through traditional methods.
- Pain during infusions of large volumes of fluids can be mitigated by preceding infusions with 2% cardiac lidocaine without epinephrine, as described earlier.
- The humeral insertion site is usually associated with faster delivery of medications and fluids to the central circulation. However, this site is also associated with a higher rate of failure and complications. The proximal tibia insertion site is generally easiest to access, and the slower delivery of medications or fluids is of uncertain clinical significance.
- Many medications or fluids that can be given through traditional intravenous access may also be delivered through IO access.

ACKNOWLEDGMENTS

Special appreciation and recognition for assistance with images and video is due to Scotty Bolleter, LP, and the staff of the Centre for Emergency Health Sciences.

RESOURCES

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Thadikonda, K. M., Egro, F. M., Ma, I., & Spiess, A. M. (2017, January). Deltoid compartment syndrome: A rare complication after humeral intraosseous access. *Plastic and Reconstructive Surgery. Global Open*, *5*(1), e1208. https://doi.org/10.1097/GOX.0000000000001208

CHAPTER 14

Ultrasound-Guided Central Venous Access

Claire Shaffer, Cara Kanter, and Keith Lafferty

BACKGROUND

Intravenous (IV) access is paramount to patient care; along with airway management, central venous access is an important procedural skill needed in managing critically ill patients. There are over 5,000,000 central lines placed annually in the United States. Mastery of this critical skill demands not only an appreciation of regional anatomy but also dexterity and competence in performing the Seldinger technique (described here). ***The use of ultrasound (US)-guided central venous access is currently the standard of care for performing this invasive procedure***. Its use has greatly reduced inherent complication rates.

Central venous catheter (CVC) access can be accomplished via the internal jugular vein (IJV), the subclavian vein (SCV), or femoral vein (FV). Although some evidence suggests an increased infection rate at the femoral site, the data are not conclusive. A Cochrane review found increased rates of CVC colonization with femoral versus supradiaphragmatic CVCs, but more important, there was no statistically significant difference among central-line associated bloodstream infection (CLASBI) rates when strict protocols were followed. A study by Parenti et al. (2015) found lower rates of infection and venous thrombosis at the subclavian site as compared to IJV or FV.

Regional anatomy impacts the use of US-assisted CVC access. For example, because the IJV has no overlying bony structures, is proximally located, and is relatively superficial, it is easily accessed using US guidance. The SCV was previously thought not to be favorable for US guidance because of its deep placement within the upper chest and bony surroundings (lies between the clavicle and the first rib); however, recent studies have shown US can also be used successfully at this site. Furthermore, the CVC technique described can be performed in other anatomical locations and may require modifications in insertion site according to regional anatomy and body habitus characteristics.

Balls, LoVecchio, Kroeger, and Stapczynski (2010) found that US guidance also reduces the number of total punctures per attempt, therefore decreasing complication risks, including CVC-associated bloodstream infection, which is known to be correlated with the number of skin puncture attempts. Fragou et al. (2011) demonstrated increased rates of SCV cannulation, decreased time to cannulation, and decreased complications related to catether placement when using US as opposed to the blind approach for placing a subclavian CVC.

Karakitsos et al (2006) compared CVC insertion via the landmark and US methods. Outcomes associated with using the landmark versus US-guided CVC approach are found in **TABLE 14.1**.

TABLE 14.1 **Ultrasound- Versus Landmark-Guided Central Vein Catheter Technique Outcomes**

Study Results	Ultrasound	Landmark
Arterial sticks	0%	54%
Needle attempts	1.5	10.4
Needle-to-vein time	58 sec	338 sec
Success rate	100%	42.8%

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

NOTE **Many advisory groups, including the National Institute for Clinical Excellence, have recommended the use of US guidance as the preferred method for elective central venous catheterization insertion for children and adults.**

No discussion of CVC would be complete without briefly describing the work of Sven Seldinger. In 1953, Sven Seldinger, a Swedish radiologist, developed and pioneered a way of accessing and cannulating large vessels deep within the body that is still used today. Using a finder needle to identify the vessel, he inserted a guide wire into the vessel through the finder needle, then, by placing a catheter over the proximal end of the guide wire, he was able to insert the catheter distally into the vessel in a progressive manner, finally removing the guide wire after the catheter was advanced deep into the vessel. This landmark-guided technique eliminated the surgical cut-down approaches previously required for CVC placement (**FIGURE 14.1**).

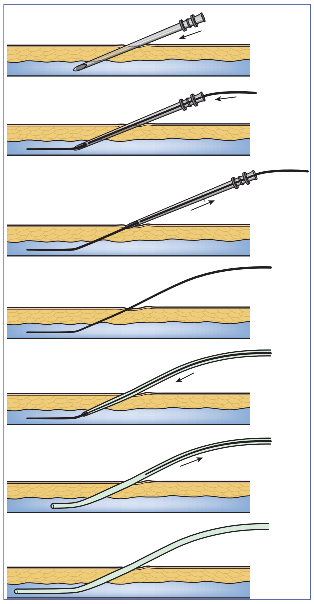


FIGURE 14.1 Illustration depicting the Seldinger technique.

NOTE **Just as the Seldinger technique eliminates the time and inherent complications of deep surgical vessel exploration, US-guided CVC placement now eliminates much of the inherent anatomical aberrancy and complications of the landmark technique.**

Anatomy

INTERNAL JUGULAR VEIN

The IJV lies in the carotid sheath adjacent to the carotid artery (CA) and vagus nerve, located in a triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle (SCM) at its superior apex and the clavicle inferiorly. It runs vertically down the neck and empties into the SCV. The right IJV is easier to cannulate compared to the left IJV because of its inherent straight trajectory to the SCV, whereas the left IJV joins at a more acute angle. In addition, the right pleural dome is smaller in diameter and lies more inferiorly compared to the left, reducing the risk of procedure-associated pneumohemothorax. In general, the IJV is superficial and lateral to the CA, but aberrancy can occur (**FIGURE 14.2**).

Studies have shown that 11% of right IJVs and 24% of left IJVs are actually medial to the CA. Troianos et al. (1996) found the right IJV to overlie most (75%) of the CA in 54% of patients, and is anterior to the CA in a majority of cases. Because of these anatomical aberrancies, there is a 9% to 11% greater risk of CA puncture when inadvertently traversing the posterior IJV wall when using the CVC landmark technique without the use of US guidance to confirm the vascular anatomy (**FIGURE 14.3**). Rotating the head to the contralateral side increases the overlap of the IJ over the CA.

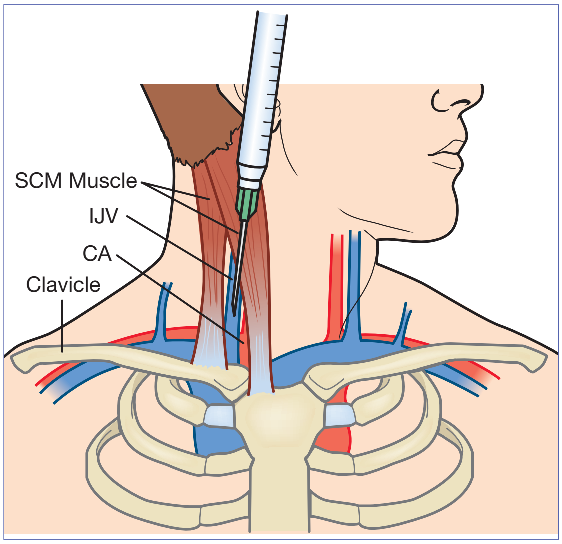


FIGURE 14.2 Needle placement in the internal jugular vein and surrounding anatomy.

CA, carotid artery; IJV, internal jugular vein.

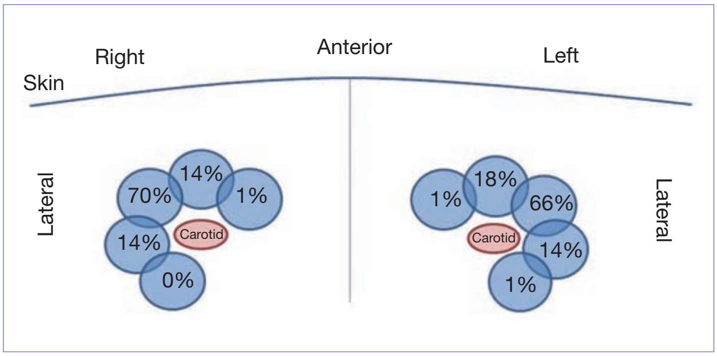


FIGURE 14.3 Aberrant relationships of the internal jugular vein and the carotid artery.

FEMORAL VEIN

The FV is most easily accessed just distal to the inguinal ligament. In a patient with a good pulse, the best anatomic landmark to use to identify the location of the FV is the femoral artery, which you should be able to palpate for pulsatile flow. The FV is located just medial to the femoral artery in its course through the fermoral triangle (**FIGURE 14.4**). The mnemonic NAVEL can help one recall the lateral to medial anatomy of the femoral triangle (Nerve, Artery, Vein, Empty, Lymphatics).

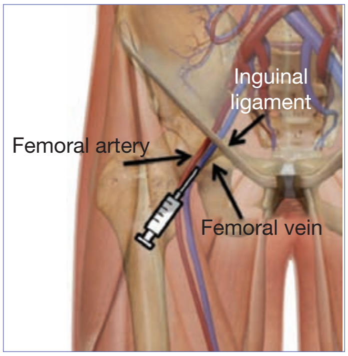


FIGURE 14.4 Anatomy and approach to the right femoral vessels.

Source: Reproduced with permission from Teleflex. Retrieved from https://www.teleflex.com/en/usa/arrowUniversity/vascular/cvc/section2/13.html

SUBCLAVIAN VEIN

The axillary vein becomes the SCV as it passes the lateral border of the first rib. At this point, the SCV is usually superficial and caudad to the subclavian artery, and can be accessed by entering the skin just lateral to the curvature of the clavicle and aiming the needle toward the sternal notch (**FIGURE 14.5**). ***This site carries the highest incidence of pneumothorax related to CVC insertion (Parenti et al., 2015), as the SCV is very close to the pleural line at this location. Although it is difficult to place a CVC under US guidance at the traditional site of entry of the SCV because of obstruction from the clavicle, accessing the axillary vein lateral to where it becomes the SCV can be achieved under US guidance***. Fragou et al. (2011) demonstrated that US-guided placement of a CVC in the axillary vein has shown decreased complication rates as compared to blind SCV cannulation. Senussi et al. (2017) recommend inserting the needle into the axillary vein at the site where it is superficial to the second rib to create one further barrier between the needle and the pleural space.

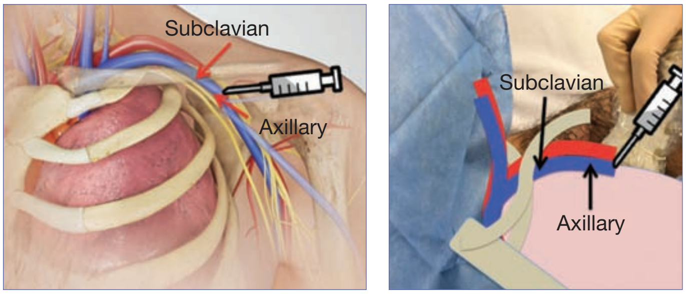


FIGURE 14.5 Anatomy and approach to the left subclavian/axillary vein.

Source: (left image) Reproduced with permission from Teleflex. Retrieved from https://www.teleflex.com/en/usa/arrowUniversity/vascular/cvc/section2/10.html

PATIENT PRESENTATION

Procedure Indications

In general, placement of a CVC is indicated in the following:

- Delivery of critical and/or caustic medications
- Emergency resuscitation
- Monitoring of central venous pressure (CVP)
- Emergency venous access after inability to achieve a peripheral IV line
- Insertion of a transvenous pacemaker/pulmonary artery catheter
- Hemodialysis

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Infection of the area overlying the deep vein
- Thrombosis of the deep vein
- Coagulopathy (relative)

PROCEDURE PREPARATION

Most supplies listed are available in commercially packaged kits (**FIGURE 14.6**).

- Full sterile barrier (sterile gloves, gown, cap, mask, and face shield)
- Chlorhexidine
- Sterile drapes to cover top half of body (or full body)
- Topical anesthetic
- Syringes
- No. 11 blade scalpel
- Sterile gauze

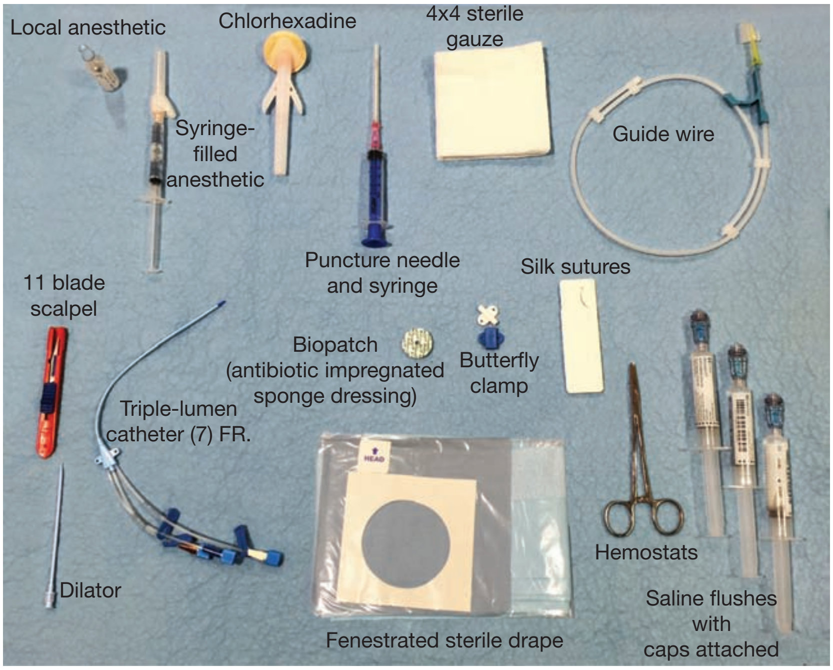

Local anesthetic
Chlorhexadine
4x4 sterile gauze
Syringe-filled anesthetic
Guide wire
Puncture needle and syringe
Silk sutures
11 blade scalpel
Biopatch (antibiotic impregnated sponge dressing)
Butterfly clamp
Triple-lumen catheter (7) FR.
Hemostats
Dilator
Saline flushes with caps attached
Fenestrated sterile drape

FIGURE 14.6 Open central venous catheterization kit.

- Catheter dilator (1 French larger than the CVC)
- Needle and wire
- CVC (single or multiple lumen)
- Silk suture
- Sterile saline flushes
- Antibiotic dressing (preferably impregnated antibiotic sponge)

Ensure proper CVC size based on clinical scenario. In general, for resuscitation or dialysis purposes, an 8.5 to 11.5 French is preferable. Otherwise, the standard triple-lumen 7 French can be used for multiple port access. Poiseuille's law dictates that the flow rate of a liquid is directly proportional to the fourth power of the conduit's radius and is inversely proportional to the conduit's length by a factor of 8 (*flow rate = radius*^{4}*/ length [8]*). In other words, use shorter, larger diameter catheters for fluid resuscitation (**FIGURE 14.7**).

Catheter radius (gauge) is extremely important when one considers the various determinants associated with Poiseuille's law. The flow rate of IV fluids is directly proportional to the fourth power of the internal radius of any tubular structure. An example of the importance of this fact clinically can be seen in the utilization of large-bore IV catheters. If all the other determinants of Poiseuille's law are held constant, doubling the diameter of an IV catheter increases the flow rate by 16 fold. ***This dramatic increase in flow rate underscores the importance of large-bore IV catheter selection when one is attempting to reach maximum flow rates for various IV fluids (TABLE 14.2).***

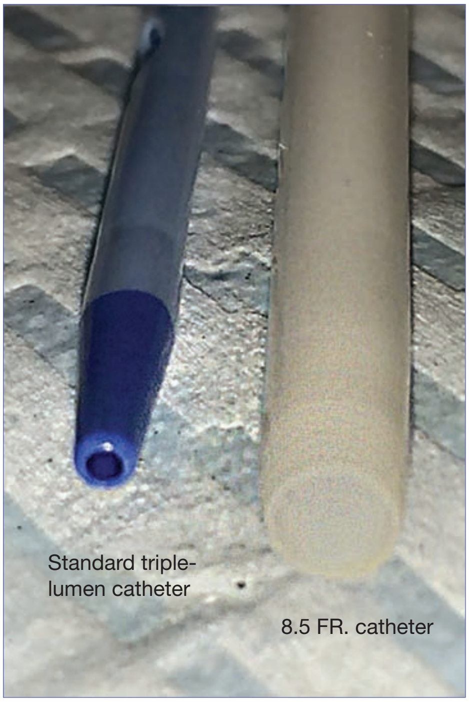


FIGURE 14.7 Comparison of standard 7.0 triple-lumen and an 8.5 French catheter.

TABLE 14.2 Various Flow Rates of Various Catheters by Gravity (Significantly Increased When Pressure Devices Employed)

Gauge	Gravity Flow Rate (mL/min)	Time to Infuse 1 L of Crystaloid (min)
14 G IV	250	4
16 G IV	150	7
8.5 French Cordis	130	8
15 G Humeral IO	80	13
Distal triple-lumen port (16 G)	70	15
Proximal triple-lumen port (18 G)	30	34

IO, intraosseous; IV, intravenous.

NOTE **Although Poiseuille's law dictates that gauge trumps other factors, one should strive to use the shortest catheter possible in terms of decreasing flow resistance.**

PROCEDURE

Identify the Anatomy

- When using the US probe, convention dictates that the clinician stand on the right side of the patient and the probe marker faces toward the patient's head or the patient's right side. This ensures the probe marker on the left side of the screen is properly aligned with the clinician's left side, and when moving the probe to the left or right the images on the screen will move in that direction as well.

- If you are placing a CVC in the right SCV or the femoral vessels, follow conventional mechanics for holding the US probe.
- If you are placing a CVC in the right or left IJV or the left SCV, you will be facing the patient's feet. Because you are not facing the patient from the normal stance, you will need to point the probe marker to the patient's LEFT in order to keep your left aligned with the left side of the screen.

Internal Jugular Vein

- Place the patient in at least a 20-degree Trendelenburg position to engorge the IJV and to decrease the risk of an air embolism.
- Turn chin slightly away from vein to be accessed, but not extremely rotated, as this tends to pull the IJ over the CA.
- If possible, use the right IJV to obtain a more direct approach to the SVC.
- Using the US probe, first identify two circular hypoechoic areas that represent the IJV and the CA. The IJV is more oval in shape and thinly walled, making it compressible. It is also usually superior and lateral to the CA. The CA is always circular, consists of a thicker muscular wall, and is not compressible (**FIGURE 14.8**). If there is any question as to which vessel is arterial, you can use color mode to look for pulsatile flow, which should be present only in the artery. Make sure you have adjusted the depth of the US field correctly.
- Identify the apex of the triangle formed by the sterno and clavicular heads of the SCM and place the US probe on the patient to identify the anatomy of the IVJ and CA. From this position, you will aim the needle toward the ipsilateral nipple. Follow the IVJ and carotid with the probe to identify a location where the vessels are side by side if possible. The anatomy may be such that the IJV is superior rather than lateral; in this case, choose the position along the course of the vessel where your approach will be most convenient.

Anatomical landmarks are used for initial probe placement, not for needle insertion and trajectory.

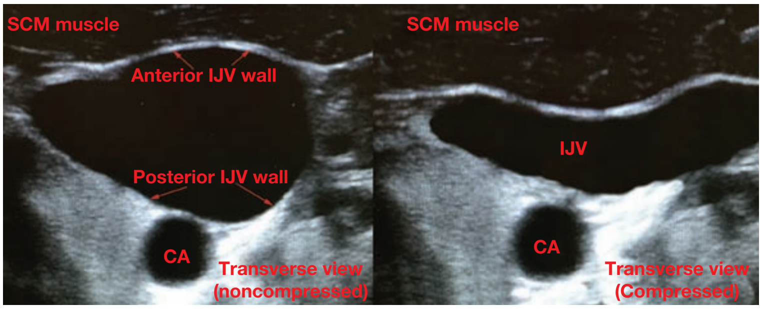


FIGURE 14.8 Ultrasound appearance of the internal jugular vein and carotid artery. Notice that the caro tid artery is noncompressible and maintains its circular form.

CA, carotid artery; IJV, internal jugular vein; SCM, sternocleidomastoid muscle.

Femoral Vein

- Lay the patient flat on the bed in a supine position.
- Identify the femoral artery just distal to the inguinal ligament. ***If the patient has a weak pulse, you can also place your thumb on the pubic symphysis and your pointer finger on the anterior superior iliac spine to approximate the location of the femoral vessels, which should be about at the angle between the two fingers.***
- Place the probe on the patient in the transverse orientation and identify the two circular hypoechoic structures that are the femoral artery and vein (**FIGURE 14.9**). ***Make sure that you have the appropriate depth on your screen; the greater saphenous vein may be mistaken for the common FV if you do not have appropriate depth.*** You should be visulalizing a structure several centimeters deep on the screen. At the level of the inguinal ligament, the thin-walled and compressible vein should be just medial to the thick-walled and noncompressible artery. You can also place color flow on the screen to distinguish between the two vessels if you are unsure.

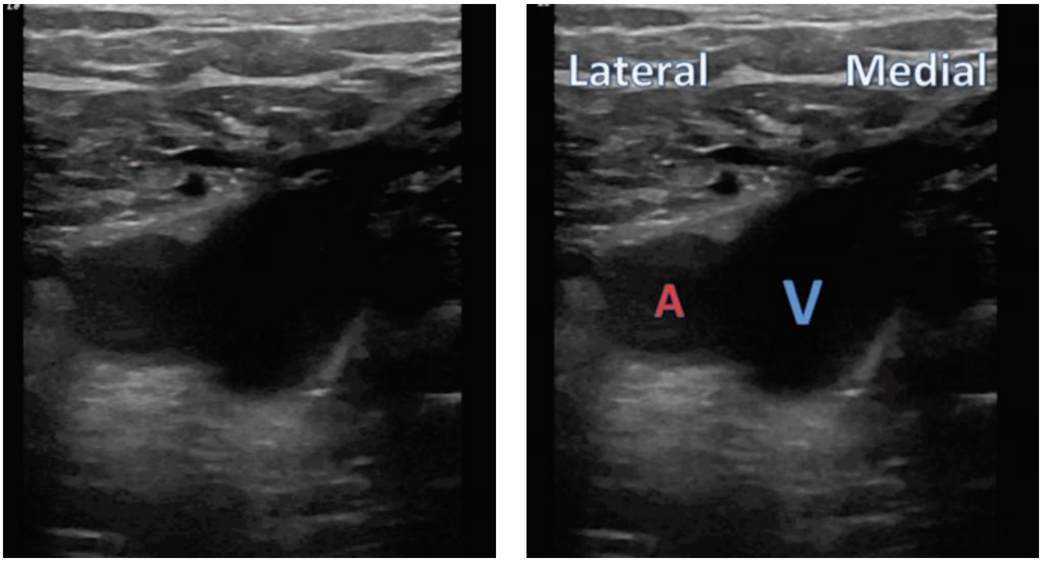


FIGURE 14.9 Unlabeled and labeled ultrasound appearance of the right common femoral vein and artery.

A, artery; V, vein.

Subclavian Vein

- Place patient in either the Trendelenburg or flat position.
- If possible, the left SCV is preferred because of its more direct course to the SVC.
- Identify the curvature of the clavicle, place the probe on the patient in the sagittal plane (perpendicular to the SCV), and identify the hypoechoic circular structure that courses under the clavicle. ***Follow this vessel 3 to 5 cm to a more lateral location***. At this point you should see two hypoechoic structures; the more caudad and superficial structure should be the thin-walled axillary vein, which should collapse with pressure, whereas the more cephalad and thick-walled structure should be the axillary artery, which should not be compressible and should have pulsatile flow if color is applied.
- Take note of the vein's course and proximity to the pleural line, which will be a hyperechoic structure located just deep to the axillary vein and axillary artery. Deep to the pleural line will be the hypoechoic tissue of the lung (**FIGURE 14.10**).

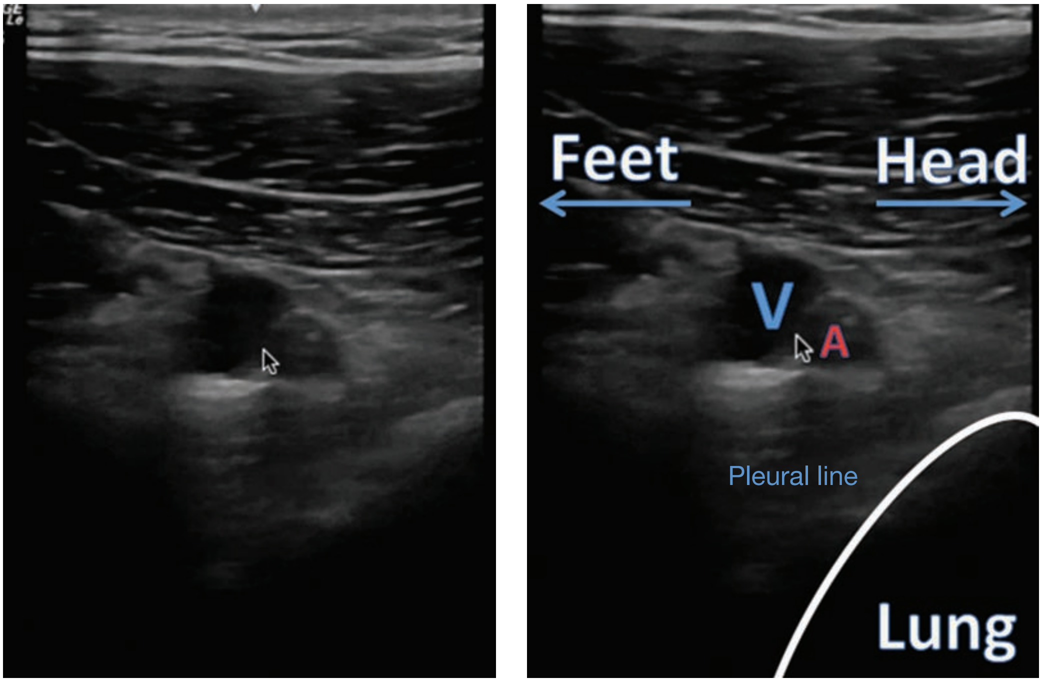


FIGURE 14.10 Unlabeled and labeled ultrasound appearance of the left axillary vein, artery, and pleural line.

A, artery; V, vein.

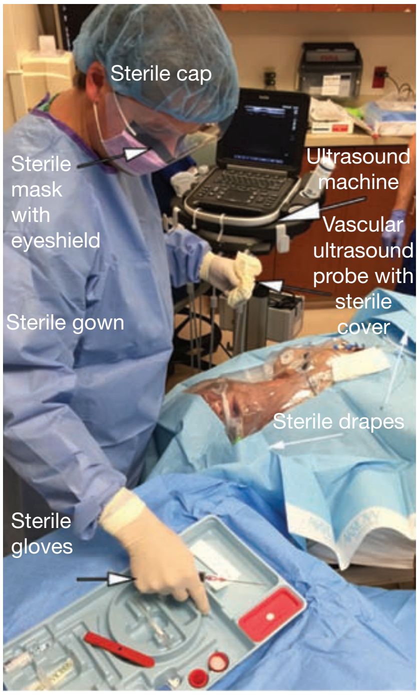
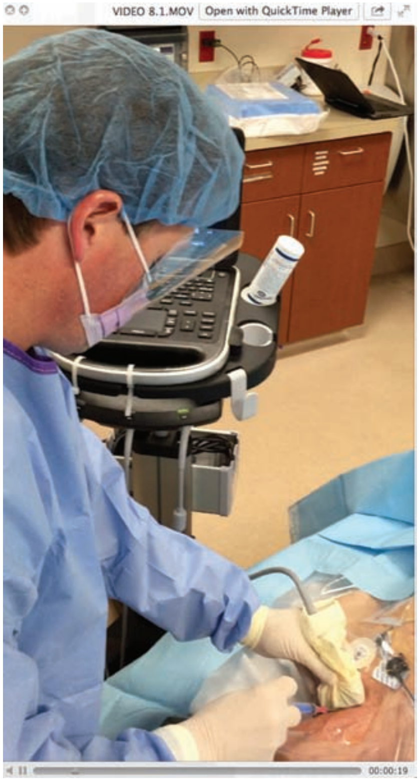

Sterile cap
Sterile mask with eyeshield
Ultrasound machine
Vascular ultrasound probe with sterile cover
Sterile gown
Sterile drapes
Sterile gloves

FIGURE 14.11 Clinician and patient barriers.



VIDEO 14.1 Internal jugular central venous catheter insertion.

Place the Line

- Put on full sterile barrier (**FIGURE 14.11**).
- Cleanse the skin with a skin cleanser, such as chlorhexidine.
- Place the US on opposite side of the bed from which you will do the procedure to allow for the most direct line of vision between the patient and screen.
- Drape the skin.
- Using an assistant, place sterile, long US sleeve with gel over probe.
- Use the sterile saline to flush each of the CVC ports to ensure the lumens are patent.
- Using your nondominant hand, place US probe directly over landmark needle insertion site using the transverse plane (**VIDEO 14.1**).
- Apply local anesthetic at the site you have identified for needle insertion.
- Remove the cap from the port in which the guide wire will be threaded ***(the longest lumen)***.
- Place the US probe on the patient so the vein is in the middle of your screen.
- Ensure needle entry site is just proximal and in the exact middle portion of the US probe.
  - When placing a CVC in the IJV, avoid penetration into the deep tissues of the neck.
  - Realize that the IJV technically is a deep vein, but, in reality, it lies relatively superficially in the neck; ***because of this, the puncture depth is rarely greater than 1.5 cm***.
- Using your dominant hand, enter the insertion site at a 45-degree angle from the coronal plane with the long access of the needle pointing toward the ipsilateral nipple for the IJV (for the SCV, point the needle toward the sternal notch; for the FV, point the needle toward the umbilicus).
- After penetrating skin, apply gentle suction.
- Follow the tip of your needle slowly through the soft tissue; begin by finding the tip of your needle, which will be bright and displacing the surrounding soft tissue. While holding the needle still, advance the probe slowly until your needle is no longer on the screen. At this point, hold the probe still and advance the needle until the tip is once again visible on your screen. Continue with this process until you reach the vessel wall.
- Observe the needle tip/shadow as it appears in the image (**FIGURE 14.12**), puncturing the vessel wall by first depressing the outer vein wall and then noticing a "bounce back return" of the vessel's original shape, followed by flash of venous blood (darker and nonpulsatile as opposed to blood from an artery). You should be able to visualize the tip of the needle in the lumen of the vessel at this point.
- Once the vessel is cannulated by the needle and return of blood via the syringe is constant, put down the US probe and use the nondominant hand to firmly grasp the hub of the needle with the thumb and index finger while the rest of the hand lies firmly on the patient's neck/lateral chest/groin depending on site (diminishes distal needle migration).
- Remove the syringe; you should notice a slow drip of venous blood.
- Place the distal/curved end of the guide wire into and through the hub and needle and advance the guide wire to its proper length (usually the proximal/straight end of the guide wire will not surpass the patient's head).

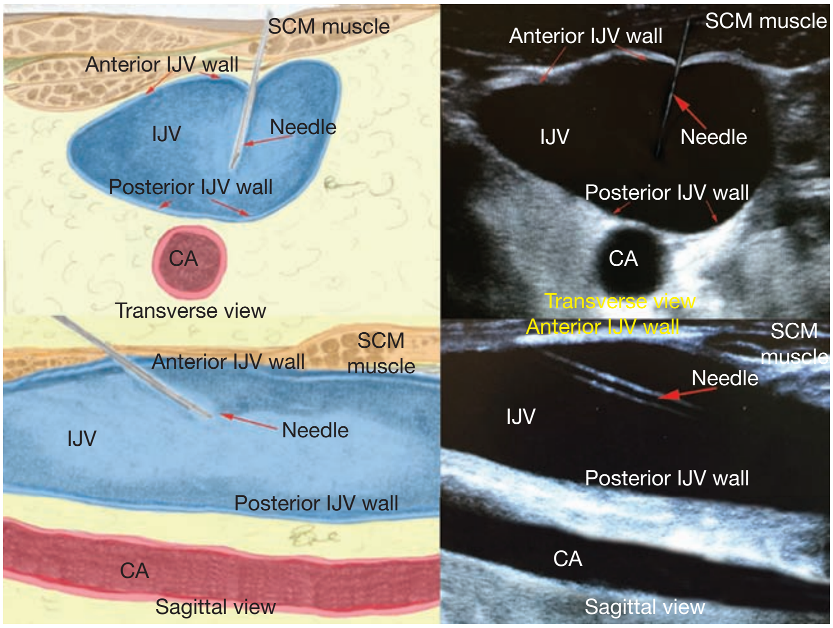

SCM muscle
Anterior IJV wall
IJV
Needle
Posterior IJV wall
CA
Transverse view
SCM muscle
Anterior IJV wall
IJV
Needle
Posterior IJV wall
CA
Transverse view
Anterior IJV wall
SCM muscle
IJV
Needle
Posterior IJV wall
CA
Sagittal view
Anterior IJV wall
SCM muscle
Needle
IJV
Posterior IJV wall
CA
Sagittal view

FIGURE 14.12 Ultrasound appearance of needle–vein cannulation of the internal jugular vein.

CA, carotid artery; IJV, internal jugular vein; SCM, sternocleidomastoid muscle.

- If a dysrhythmia occurs during the procedure, the guide wire may be irritating the myocardium and should be withdrawn slowly until the dysrhythmia reverses.
- ***If unable to pass the guide wire through the needle, the needle may have inadvertently pierced the posterior vessel wall. In this case, the wire should be removed***. Place a syringe on the needle hub and apply gentle suction, then place the US back on the patient and find the tip of the needle. ***The longitudinal view may be most useful in this instance***. Use the US to reposition the tip of your needle while continuing to apply gentle suction until blood returns again. At this point, detach the syringe and attempt to thread the guide wire again.

- **Never let go of the guide wire**.
- Once you have successfully threaded the guide wire, place the probe back on the patient in the longitudinal plane to visualize the course of the guide wire through the soft tissues into the lumen of the vessel (**FIGURE 14.13**).
- Withdraw the needle, leaving the guide wire in place by retracting the needle out of the skin with the nondominant hand, using the dominant hand to hold the proximal end of the guide wire.
  - If resistance is encountered when removing the guide wire through the needle, remove both as one unit to reduce the risk of shearing and creating a guide-wire embolism.

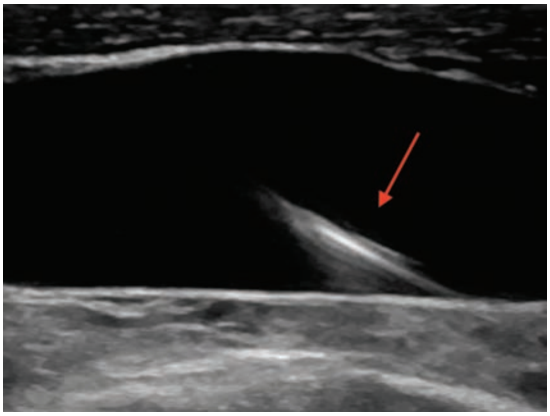
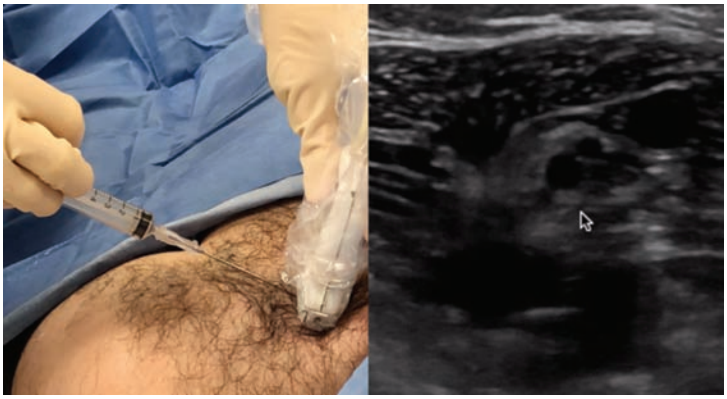


FIGURE 14.13 Guide wire (*red arrow*) visualized in the lumen of the internal jugular vein.

- Once the needle is completely out of the skin, use the nondominant hand to grasp the distal end of the guide wire while the dominant hand retracts the needle fully off the guide wire. At no point should you ever let go of the wire.
- Using the scalpel with the sharp end caudal, make a small catheter-sized incision at the point of the guide wire–skin interface in a vertical plane through the dermal tissue ***but not into the carotid sheath***.
- Place the dilator over the guide wire and with a twisting motion pass it through the skin to an approximate depth of 2 cm.
  - Now use the nondominant hand to hold the proximal end of the guide wire as the dilator penetrates the skin.
- Remove the dilator while always having a hand on the guide wire.
- Apply gauze to minimize bleeding after dilator removal.
- Place the CVC over the guide wire just until it is proximal to the skin. (If the guide wire was initially advanced too far, use the nondominant hand and retract the guide wire at the skin until it appears in the open proximal port of the CVC.)
- Using the nondominant hand, grasp the proximal end of the guide wire and insert the CVC with the dominant hand to the appropriate depth.
  - Ideal catheter tip position is in the SVC proximal to the right atrium, which is usually achieved with a 15-cm catheter in the vast majority of adult patients when using either the IJ or subclavian site (**VIDEO 14.2**). ***Catheter position can be visually estimated and adjusted for in smaller patients or calculated using the formula height (cm)/10.***
- Stabilizing the CVC in place, remove the guide wire fully. Occlude the now-open port with a thumb to prevent air embolism until a cap is placed on the open port.
- Check for blood return and flush all ports with normal-saline syringes and ensure caps are secure on all hubs.
- Apply impregnated antibiotic sponge and secure CVC using silk sutures.
  - Patient mortality rates associated with CLABSIs range from 12% to 25% and the cost per episode of care ranges from $3,700 to $36,000.
  - Ruschulte et al. (2009) have shown that using impregnated antibiotic sponge dressings decreased CLABSIs by 46%.
  - A recent study by Karlnoski and colleagues (2019) in *the Journal of Intensive Care Medicine* demonstrated a further 46% decrease in the rate of CLABSIs using a newer silver-plated dressing compared to the standard chlorhexidine gluconate-impregnated sponge.
- Apply sterile dressing (**FIGURE 14.14**).



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VIDEO 14.2 Subclavian central venous catheter insertion.

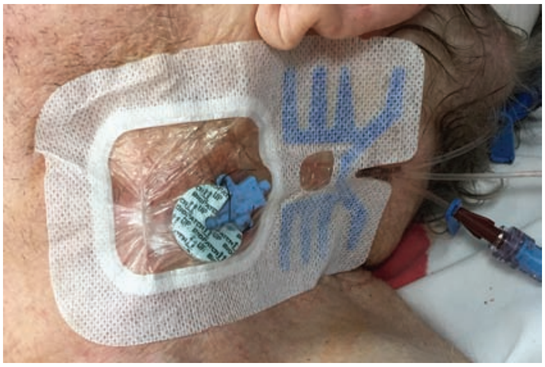


FIGURE 14.14 Impregnated antibiotic sponge under sterile dressing.

POSTPROCEDURE CONSIDERATIONS

- Order a chest x-ray to ensure proper tip depth and to ensure there is no iatrogenic pneumo/hemothorax (not required for FV).
- The postprocedure chest x-ray is not used in determinating CVC use, but rather to view the tip's anatomical position and to assess immediate complications.
- The insertion site should be re-checked after a period of time for bleeding, displacement, or hematoma formation and should be checked periodically thereafter during hospitalization for signs of malfunction or complications.

EDUCATIONAL POINTS

- Since 1996, US-guided CVC placement has been shown consistently to be superior to the landmark technique in decreasing complications and procedure duration.
- IJV clots have been incidentally identified in 2% to 4% of patients undergoing US-guided CVC upon initiation of the procedure.
- When using the US, try to visualize the tip of the needle at all times; the transverse view, although excellent for lateral/medial orientation, is not as good as the sagittal/longitudinal view in assessing needle depth to avoid penetration through the IJV posterior wall and inadvertent CA puncture. Move the US probe just distal to where the hyperechoic needle disappears to determine where the tip of the needle is in the out-of-plane technique.
- If arterial puncture occurs, remove the needle and place firm pressure for 10 minutes or until there is no bleeding.
- Curved or "J" guide wires are used to negotiate the tortuous turns of vessels.
- The guide wire is easy to visualize via US, even by novice users, and may actually be easier to visualize than the needle.
- Visualizing the guide wire in the vein prior to placement of the catheter can reduce the mechanical complication rates of CVC placement as well as decrease malpositioning of the catheter, which has been shown by small-scale studies.
- Sonographic visualization of the wire prior to passing the catheter can confirm correct placement.
- Apply a sterile dressing before removing the sterile field.
- With the application of strict protocols, ICU CLASBIs have decreased from 2001 to the time of this printing from 49,000 to 16,000 cases annually.
  - Each CLASBI is associated with increased hospital length of stay (22 days) and increased mortality rates of 12% to 25% (4,000 patients die annually).
- LeMaster et al. (2010) found that ED-placed CVCs have similar infection rates (<2 per 1,000 catheter days) when compared to those placed in ICUs; therefore, when proper aseptic insertion techniques are followed within the ED it is not recommended that ED-placed CVCs be removed upon transfer to the ICU.
- CLASBIs are correlated with the number of skin puncture attempts.
- Antiseptic-impregnated CVCs have been shown to induce a five-fold decrease in CLASBI as compared to normal CVCs and are recommended when the CVC is to remain in place for longer than 5 days.
- CLABSIs are preventable; use sterile technique and impregnated antibiotic sponge/dressings.
- Miles, Salcedo, and Spear (2012) prospectively showed that regardless of past experience, with proper guidance a 2-hour training session on the use of US-guided CVC placement promotes clinical proficiency in this skill.
- A 13-year observational study has shown that nurse practitioners and physician assistants can perform CVC placement with success; their complication rates are similar to those of physicians.
- Many advisory groups, including the National Institute for Clinical Excellence (NICE), have recommended the use of US guidance as the preferred method for elective CVC insertion for children and adults.

COMPLICATIONS

Leung, Duffy, and Finckh (2006) found that US not only increased the success rate of IJV placement by 15.4% but also decreased the overall complication rate by 12.3% as compared to the landmark technique (15%–2.7%). Complications are classified as immediate or delayed.

Immediate

- Arterial puncture (4.2%)
- Hematoma (0.72%)

- Pneumothorax (0.67%)
- Hemothorax (0.05%)
- Air embolism (0.1%)
- Guide-wire embolism (**FIGURE 14.15**)
- Dysrhythmia (0.3%)

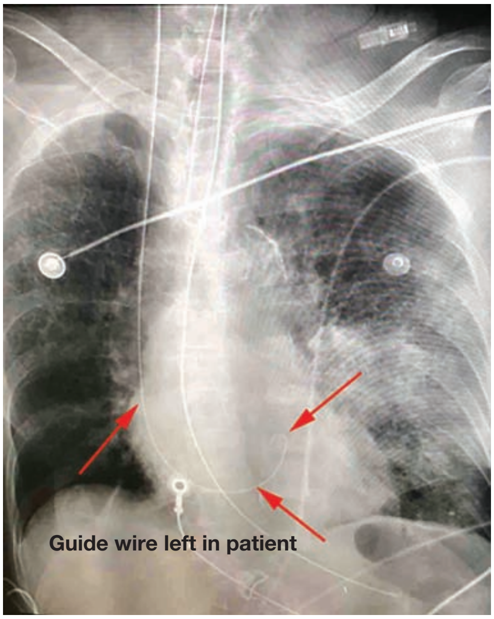


FIGURE 14.15 Chest x-ray of guide wire embolism.

Delayed

- Infection
  - CLABSI
  - Local cellulitis
- Deep vein thrombosis (0.2%)
- In a landmark perspective study, Pronovost et al. (2006) evaluated 103 ICUs, including 1,981 months of data, and concluded that the following practices decrease rates of CLABSIs:
  - Handwashing
  - Full-body precautions during insertion (repetitive studies have shown that this is one of the most effective practices in preventing CLABSI)
  - Chlorhexidine skin cleansing (numerous studies have shown its effectiveness in preventing CLABSI)
  - Removal of unnecessary catheters (decreases bacteremia rate and possible seeding of other catheters)
  - Utilizing a daily checklist
  - Avoidance of the femoral site when possible (other studies, such as a Cochrane review, have shown that this insertion site is not independently associated with development of CLASBI when a strict protocol is followed)
- Other practices associated with decreasing CLASBI rates to less than 1 per 1,000 catheter days include
  - Use of a checklist
  - Daily assessment of the continued need of the CVC
  - Daily assessment of the insertion site
  - Handwashing and cleansing hub with alcohol before use

PEARLS

- The more obese the patient, the more likely the landmark technique will result in inaccurate placement.
- Having the patient in the Trendelenburg position and/or performing a Valsalva maneuver increases the IJV size.
- Turning the patient's head 45 degrees or greater increases the overlap of the IJV in relation to the underlying CA.
- Anatomical landmarks are used for initial probe placement, not for needle insertion and trajectory.
- US has been shown to decrease the risk of pneumothorax to almost 0%. Just as the Seldinger technique eliminates the time and inherent complications of deep surgical vessel exploration, US-guided CVC placement now eliminates much of the inherent anatomical aberrancy and complications of the landmark technique.
- IJV depth is rarely greater than 1.5 cm below the surface of the neck.
- Have an assistant prearrange sterile flushes with caps already placed on the tray at the start of the procedure.
- If there is continued difficulty obtaining blood return through the needle in the initial puncture, remove the needle and flush with sterile saline as a blood clot may have formed in the needle itself.
- In hypotensive or hypoxic patients, pulsatile or red blood flow return may not be apparent following arterial puncture.

- Never let go of the wire during the procedure.
- If one should encounter resistance, never force the guide wire through the needle.
- Generally, one does not need to pass the guide wire further than the patient's head during the entire procedure, as it needs to be advanced only far enough to maintain reliable control of the tract from the skin surface to the intravascular space (if the guide wire requires withdrawal through the catheter for control of the proximal/rigid end, the guide wire was inserted too far).
- After the syringe is removed and before the wire is inserted (and the same goes for when the CVC is placed and the guide wire is removed), one should occlude the catheter by placing the thumb over the needle hub in order to prevent an air embolism.
- Teismann et al. (2013) found that when using an 18-gauge, 2.5-inch peripheral intravenous catheter (IVC), one can cannulate the IJV using US guidance and in essence have a "peripheral IJ" with no reports of spontaneous migration out of the vein lumen (**FIGURE 14.16** and **VIDEO 14.3**).
- In a prospective manner, Zitek et al. (2018) showed that after a 150-minute video tutorial, attendings and residents were 97.1% successful in the US placement of an 18-gauge IV single-lumen catheter with a median time of 3 minutes and 6 seconds.

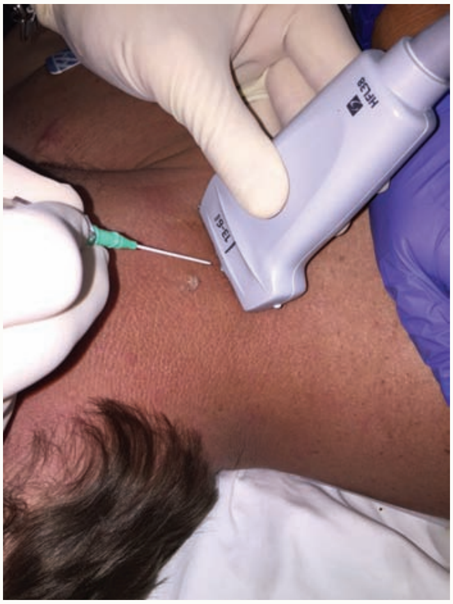
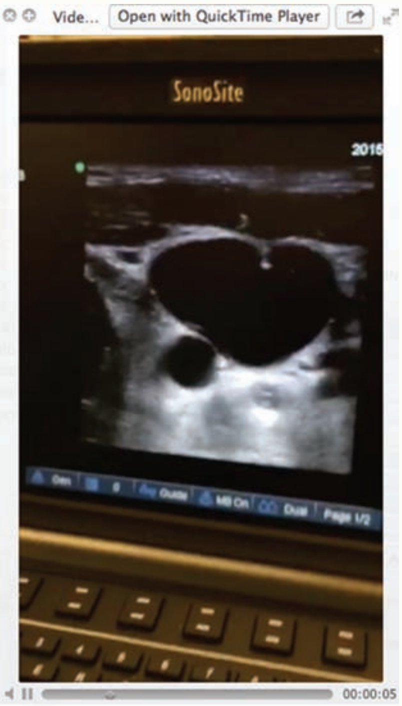


FIGURE 14.16 Peripheral internal jugular insertion. Although thus far the body of literature is still relatively small, it suggests that the use of a peripheral internal jugular vein is a safe and suitable alternative in appropriately selected patients who have no other feasible routes of vascular access, and in whom the insertion of an intraosseous or central line is otherwise unnecessary.



VIDEO 14.3 Peripheral internal jugular vein insertion.

RESOURCES

Akhter, M., Runde, D., & Lee, J. (2013). Which central line insertion site is the least prone to infection? *Annals of Emergency Medicine*, *61*(3), 362–363. https://doi.org/10.1016/j.annemergmed.2012.10.002

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CHAPTER

15

Arterial Line Placement

Ryan C. Gibbons

BACKGROUND

The origins of the arterial line can be traced back to the early 1700s when Stephen Hales first cannulated a horse. In 2002 alone, clinicians placed over 10 million arterial lines worldwide. Presumably, this figure is far greater now as our aging, more critically ill population continues to grow. In fact, over one third of intensive care unit patients will have an arterial line placed at some point during their hospitalization. It is interesting to note that arterial line utilization continues to increase despite the lack of evidence demonstrating that it improves clinical outcomes. In fact, there's never been a randomized controlled trial (RCT) showing that arterial lines improve outcomes even in septic shock. It remains a matter of debate whether invasive blood pressure (BP) monitoring is even needed. Nonetheless, most clinicians believe that some patients benefit from continuous, invasive arterial BP monitoring (especially those on higher doses of vasopressors).

Historically, radial arterial lines have been utilized 5 times more often than common femoral lines and 10 times more frequently than axillary ones. Traditional teaching advocates for radial lines given their ease of access and reportedly fewer complications. However, current literature demonstrates similar complication rates among radial, common femoral, and axillary lines.

Prior to the introduction of point-of-care ultrasound (POCUS), landmark-guided palpation was considered the standard of care for arterial line placement. However, anatomic landmarks are not helpful in 30% of patients. Moreover, patient body habitus and hemodynamic instability (i.e., hypotension) significantly limit the accuracy of palpation.

POCUS has become ubiquitous in nearly all fields of medicine. Initially, the implementation of ultrasound guidance for peripheral and central venous access decreased the number of complications and failure rates while improving first-pass success. Similarly, more recent evidence regarding ultrasound guidance for arterial cannulation demonstrates improved first-pass success rates and time to access while reducing failure rates (by >50%) and complications. This improvement was seen across all patient populations, including adult, pediatric, and neonatal patients. Moreover, not only did ultrasound outperform palpation, but with respect to number of attempts and arterial punctures, time to completion, and complications (reduced by 59%), it also outperformed fluoroscopy.

Understand, though, there is significant heterogeneity within these studies and meta-analyses, including patient population, operator experience, clinical setting, and ultrasound technique. Nonetheless, substantial evidence exists supporting the use of POCUS for arterial catheterization. In fact, numerous national and international medical organizations and societies now mandate ultrasound guidance as the standard of care for vascular access, including arterial cannulation.

Noninvasive Versus Invasive BP Monitoring

As with any invasive procedure, we need to be prudent with our implementation of arterial lines, especially given there is no evidence to support their use. Their overutilization stems from an incorrect assumption regarding the lack of reliability of noninvasive BP (NIBP) measurements. On his critical care website, Dr. Josh Farkas provides a detailed

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

overview of noninvasive and invasive mean arterial pressure (MAP) measurements, utilizing cuff versus arterial catherization. In short

- NIBP is within +/− 12 mmHg of radial arterial line MAP.
- Radial arterial line is within −15 and + 5 mmHg of femoral arterial line MAP.
  - Femoral A-line insertion often prompted substantial reductions in vasopressor dose after concluding that the radial arterial line pressure was underestimating central arterial pressures.
  - Studies consistently show lower peripheral readings (arterial) compared to central readings (femoral) though not to the extent of 15 mmHg as indicated earlier.
  - Studies have shown that the lower the MAP (sicker the patient), the larger the discrepancy between radial and femoral readings.
  - Overall, the correlation between cuff and radial artery MAP isn't hugely different from the correlation observed between radial and femoral artery line pressures.
  - Radial arterial pressure represents hand perfusion, whereas central arterial monitoring represents aorta pressure and hence perfusion of the most critical organs in a shock state:
    - Heart
    - Brain
    - Kidneys
  - Electronic sphygmomanometers are being refined for continuous indirect BP monitoring and may eventually replace arterial canalization.

Traditionally, it has been assumed that all invasive BP sites are equal in regard to measurements. However, the literature suggests that this model is wrong. Specifically, the radial and femoral BP diverge among the sickest patients (e.g., patients undergoing cardiopulmonary bypass or liver transplantation). In such patients, the radial arterial pressure may be misleadingly low, with a potential to instigate excessive vasopressor and fluid administration.

The evidence advocates for the use of NIBP in the majority of patients, except perhaps those in severe shock (multiple vasopressor agents) or who are not improving clinically despite adequate resuscitation.

If utilized, central arterial access is preferred given its more accurate MAP. Furthermore, evidence suggests common femoral lines are less likely to fail than peripheral ones and have the same complication rate.

PATIENT PRESENTATION

Indications

- Hemodynamic monitoring
- Cardiopulmonary resuscitation, including extracorporeal membrane oxygenation (ECMO)
- Cardiac catheterization
- Frequent arterial blood gases (ABG)
  - This is no longer a standard indication given the accuracy of venous blood gas (VBG; **TABLE 15.1**).

TABLE 15.1 Correlation Between Venous and Arterial Blood Gases

pH	0.035 units mean difference (−0.11 to + 0.07 95% LoA), *n* = 1,252 −0.033 mean difference (95% CI 0.029 to 0.038), *n* = 1,747
$PaCO_2$	5.7 mmHg mean difference (+/− 20 mmHg 95% LoA), *n* = 760 4.1 mmHg mean difference (−10.7–2.4 mmHg 95% CI), *n* = 1,768
HCO_3–	−1.41 mmoL/L mean difference (−5.8–+5.3 mmoL/L 95% LoA), *n* = 905
CO	−0.15% mean difference (95% CI, 0.13%–0.45%); *n* = 61 Prospective, single center ED with hyperbaric chamber
Lactate	0.08 mmoL/L mean difference (−0.27–0.42 mmoL/L 95% LoA) Multicenter, medical intensive care unit patients, *n* = 167 No difference, *n* = 375 r^2 = 0.94 (95% CI 0.94–0.96) Single center, trauma patients only

CI, confidence interval; LoA, limits of agreement.

- ABG indications include the following:
  - Pulse oximetry (SpO_2) is not available
    - Almost never
  - Hemoglobinopathies
- Venous and arterial $PaCO_2$ values
  - $PaCO_2$ less than 45 mmHg
    - Rules out hypercarbia (or hypercapnia) with 100% sensitivity
  - $PaCO_2$ greater than 45 mmHg, poor correlation but trend together
    - Clinically correlate with the patient's status (i.e., work of breathing, mental status, SpO_2) and directional changes in venous $PaCO_2$
- Notably, VBGs are not accurate in severe shock or cardiac arrest

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Absolute
  - Absent pulse
  - Overlying infection
  - Planned harvest for coronary artery bypass grafting (CABG)
  - Femoral–femoral or femoral–popliteal bypass
  - Abnormal collateral flow
    - Anatomic
    - Raynaud's disease
    - Thromboangiitis obliterans (Buerger's disease)
- Relative
  - Coagulopathy (international normalized ratio [INR] >1.5)
  - Thrombocytopenia (platelets <50,000)
  - Overlying burn
  - Prior surgery
- Risk factors for complications
  - Patient
    - Anatomic variants (>30% of patients)
    - Poor collateral flow
      - Peripheral arterial disease
      - Atherosclerosis
      - Calcifications
    - Diabetes
    - Peripheral arterial disease
    - Tobacco use
    - Scleroderma
    - Need for prolonged vasopressors (i.e., severe shock)
    - Need for prolonged catheter placement
  - Operator
    - Inexperience
    - Multiple attempts

PROCEDURE PREPARATION

- Sterile technique
  - Gown, gloves, cap, and mask
  - Drapes
  - Ultrasound gel and transducer cover
  - Dressing kit
  - Prepare 2 to 3 cc of local anesthetic without epinephrine
    - There are no theoretical complications in regard to the induced vasoconstriction of epinephrine
- Position of patient based on point of arterial access (e.g., radial, femoral).
- Nursing
  - Monitor
  - Pressure bag (inflate to 300 mmHg) and 500-cc normal saline bag

  - Transducer kit, holder, and pressure cable
  - Ensure setup is complete prior to inserting arterial catheter
- Single versus two-operator ultrasound-guided central venous access
  - Randomized control trial; single center with N = 44
  - There was no difference in success rate or complications
  - No studies available for arterial lines

ULTRASOUND GUIDANCE

Key Points

- Landmark is not standard of care given the following:
  - *Anatomical variants in 30% of patients*
    - Radial artery is less than 3 mm, mobile, calcified, and collapsible
  - Body habitus and hemodynamic stability (i.e., hypotension)
  - Availability of POCUS and the evidence supporting its use
- *Ultrasound is standard of care*
  - Utilize to differentiate artery and vein as well (**TABLE 15.2** and **FIGURE 15.1**)
  - POCUS-guided cannulation is the standard of care and is associated with
    - Increased first attempt success rate
    - Fewer overall attempts
  - Lower incidence of hematoma formation
- *Central access is preferred over peripheral arterial access*

There is a lack of evidence for use of a modified Allen's test to predict adequate collateral flow and ischemic complications. In a meta-analysis, Romeu-Bordas & Ballesteros-Peña (2017) evaluated the reliability and validity of the modified Allen's test in screening for collateral circulation deficits in the palm and for predicting distal hand ischemia and found the overall sensitivity for such at 77% and 93% overall, respectively. A single study assessing the test's reliability reported an interobserver agreement rate of 71.5%.

TABLE 15.2 Arterial and Venous Characteristics

	Artery	Vein
Wall	Thick	Thin
Compressible	Minimally	Easily
Calcifications	Common	Absent
Pulsed-Wave Doppler	Pulsatile flow*	Respirophasic variation**

*Color flow (directionality) typically not helpful (blue: flows away from transducer, red: flows toward the transducer.)

Venous collapse with inspiration and expansion (more plethoric) with expiration (see **FIGURE 15.1).

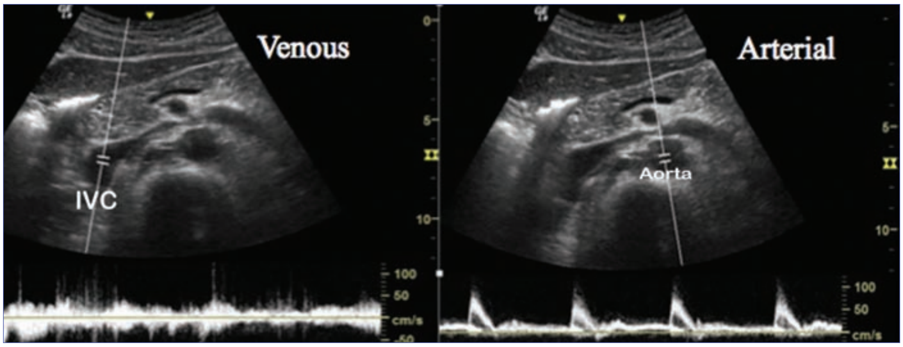


FIGURE 15.1 Pulsed-wave Doppler flow: Arterial versus venous. Note the respirophasic IVC compared to the pulsatile flow in the artery (aorta).

IVC, inferior vena cava.

The hand is normally supplied by blood from both the ulnar and radial arteries, which they join via the superficial and deep palmar arches. If the blood supply from one of the arteries is cut off, the other artery can supply adequate blood to the hand secondary to this dual arterial supply (**FIGURE 15.2**). Of note, the superficial palmar artery (mainly derived from the ulnar artery) is the major arterial supply to the digits. A minority of people lack this dual blood supply.

- Note there are less subjective alternative methods for assessing blood flow after compression of the radial and ulnar arteries and release of one; again there is limited supportive data on the various methods.
    - SpO_2
    - Doppler ultrasound
    - Direct digital pressure
        - Starnes et al. (1999) have shown that 50% of extremities with an abnormal modified Allen's test actually had a direct digital pressure within the normal range (false positives) and 9% of extremities with a negative modified Allen's test were found to have an abnormal direct digital pressure measurement (false negatives).
- Modified Allen's test (**FIGURE 15.3**, **TABLE 15.3**)
    - With the arm raised, ask the patient to clench their fist for 30 seconds or alternately in a repeated manner until blanching occurs, keeping the fist clenched at the end.
    - Apply firm occlusive pressure to both the radial and ulnar arteries proximal to the area of catheter placement (**FIGURE 15.3A**).
    - Ask the patient to unclench their fist while releasing the pressure on the ulnar artery (**FIGURE 15.3B**).
    - Note the time for capillary refill (**FIGURE 15.3C**).
        - Greater than 5 seconds is abnormal but there are conflicting data across studies regarding what defines an abnormal time (3–15 seconds).
    - Limit overextension of the hand and widespread fingers as this can produce false negatives.
    - Repeat with the radial artery.
    - If abnormal, use alternate site.

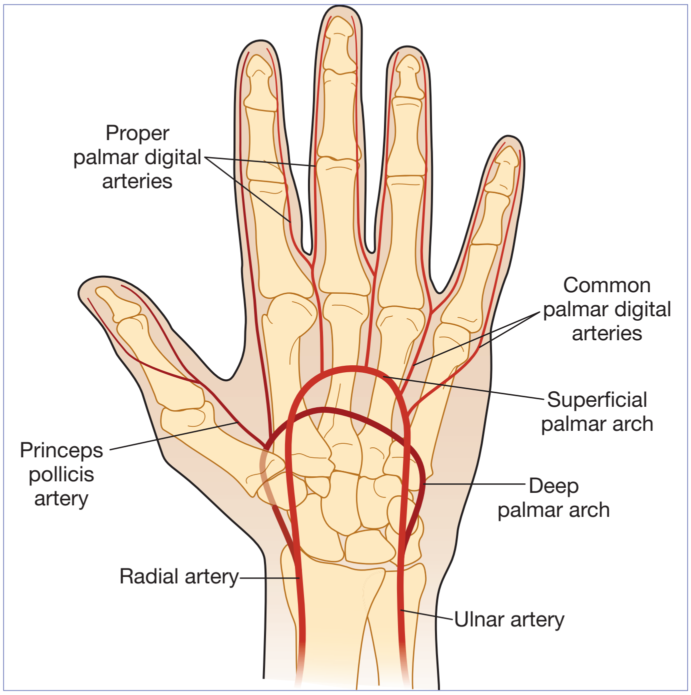


FIGURE 15.2 Arteries of the hand.

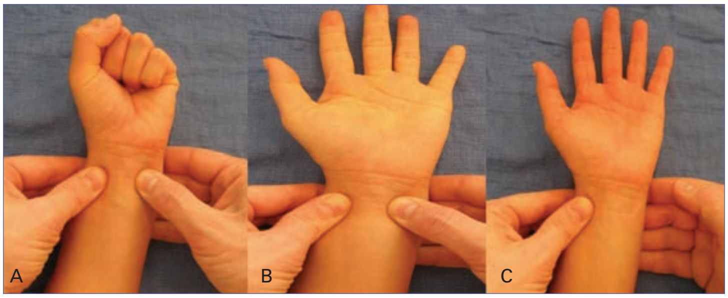


FIGURE 15.3 Modified Allen's test.

TABLE 15.3 Sensitivity, Specificity, and Accuracy of the Modified Allen's Test (%)

	3 seconds	5 seconds	6 seconds
Sensitivity	100	76	55
Specificity	27	82	92
Accuracy	52	80	79

Steps

- Complete monitor and transducer setup prior to initiating arterial cannulation.
- First, view the area to locate the ideal insertion point.
  - If unavailable, assess anatomic landmarks initially (see text that follows).
- Maintain sterility throughout the procedure.
  - Apply antiseptic to puncture site.
  - Utilize a sterile transducer cover.
- Inject 2 to 3 cc of local anesthestic without epinephrine.
- With the probe (or transducer) in the short axis/transverse (out of plane technique), center the artery on the ultrasound monitor (**FIGURE 15.4**).
  - Align the catheter with the transducer midline.
- The long axis/sagittal (in-plane technique) is technically more challenging but allows visualization of the entire needle (**FIGURE 15.5**).
  - Use of this technique is helpful to avoid puncturing the back wall.
  - Use to confirm needle, wire, and catheter placement.
- Insert the catheter just distal to the transducer at a 30- to 45-degree angle.
  - It may be necessary to use a steeper angle initially to puncture the skin and the artery.
  - Once the skin is punctured, advance the needle using dynamic needle-tip guidance.
  - Upon penetrating the artery, flatten your angle of approach to near parallel with the patient's extremity to avoid perforating the back wall of the artery.

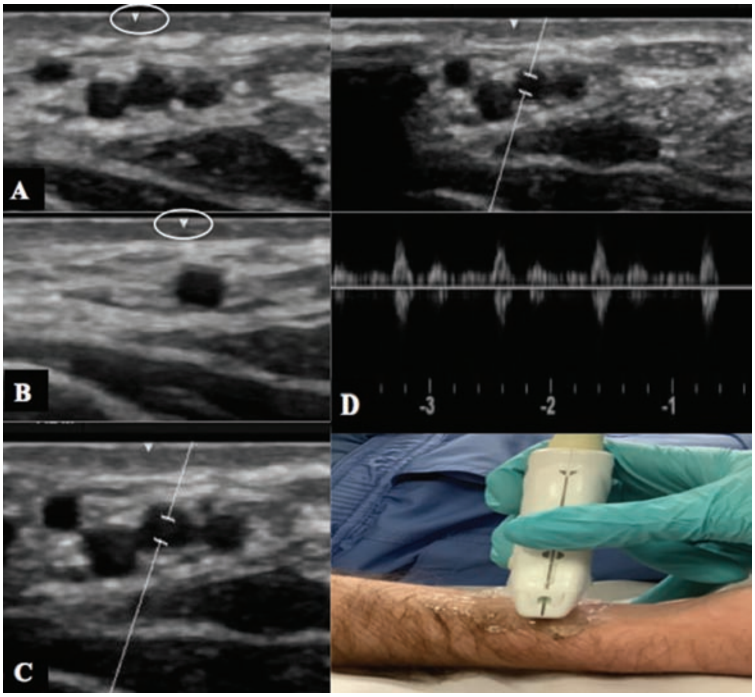


FIGURE 15.4 Transverse (short axis or out of plane) view of right radial artery. (A) Align transducer over the artery using the arrowhead. (B) Veins compressed with visible non-compressible radial artery. (C and D) Doppler arterial flow.

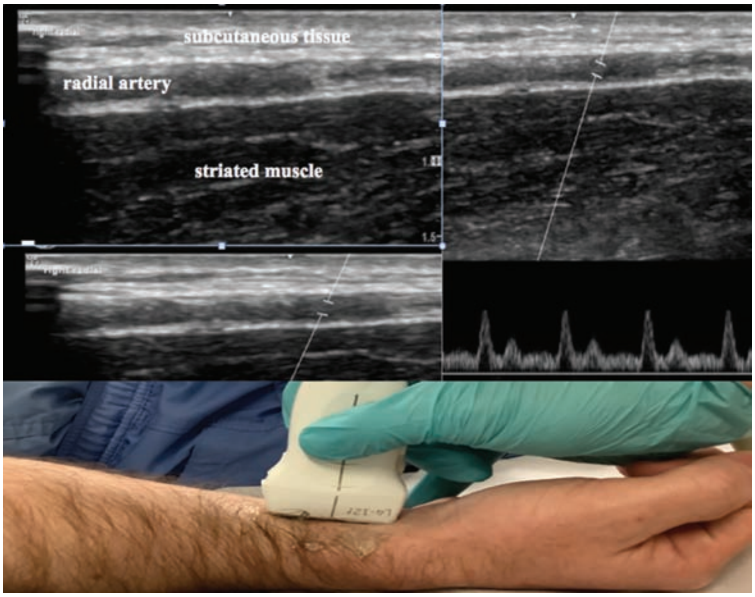


FIGURE 15.5 Sagittal (longitudinal axis or in plane) view of right radial artery.

- It is important to limit the angle of entry into the artery as an acute angle may penetrate the vessel back wall. Further manipulation/forcefulness of the wire may allow for kinking of the wire and subsequent retrieval of this crinkled wire may lacerate the artery (**FIGURE 15.6**).
- When the needle is perpendicular to the transducer, image quality is best since the acoustic beam is reflected directly back to the probe with an angle of incidence of zero. In the transverse view, or short axis, tilt the transducer slightly away from the operator to maintain a 90-degree angle (**FIGURE 15.7**). Similarly, utilizing a shallower angle of insertion will augment visualization of the needle tip.
- Use dynamic needle-tip positioning to advance the needle from the point of skin insertion to arterial puncture (**VIDEO 15.1**).
  - Hold the probe still while moving the needle proximally into view.
  - Then hold the needle stationary and slide the transducer a few millimeters proximally.
  - Now, move the needle into view and repeat this process until the needle is centered a few centimeters proximally within the artery and pulsatile blood is returned.
- Advance the guide wire as indicated on the tube marking.
- Remove the needle while holding the guide wire securely.
- Slide the catheter over the wire from the point nearest skin insertion.
  - A twisting motion may help.
  - A small incision may be necessary in certain patients.
- Remove the guide wire.
- Connect the transducer.
- Suture the catheter in place.
- Cover with sterile dressing.

The sequential steps of femoral arterial line insertion can be viewed in **FIGURE 15.8**. Please see **FIGURE 15.9** for the supplies needed for insertion of an arterial line.

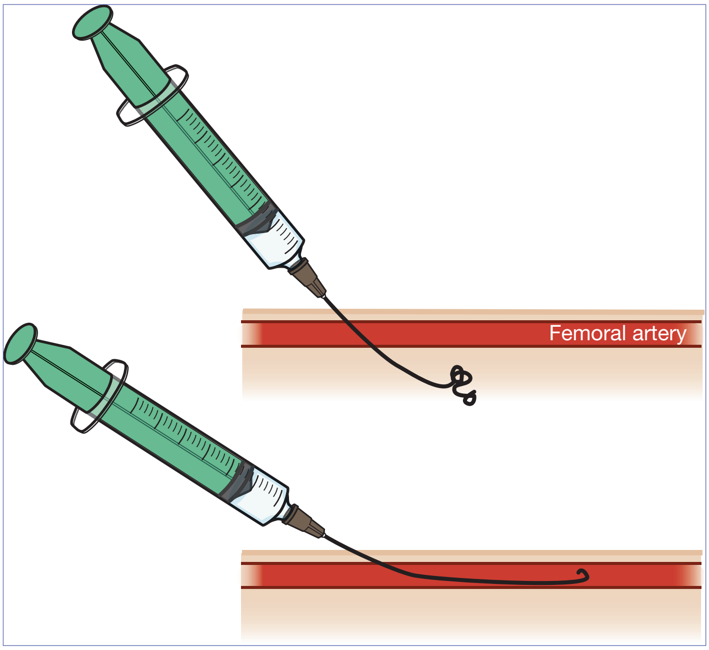


FIGURE 15.6 Kinked wire from forceful manipulation.

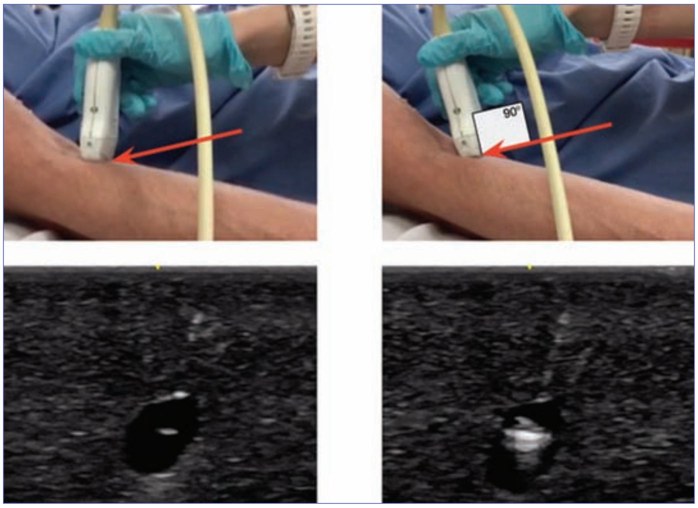
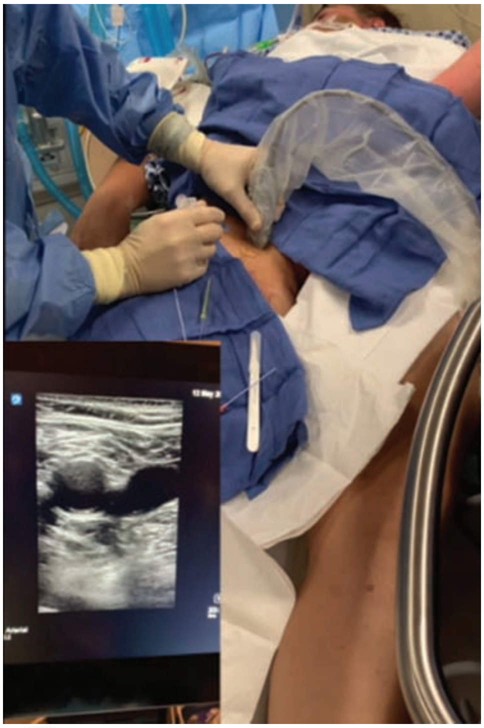


FIGURE 15.7 Adjust angle of incidence to 90° to improve visualization of needle tip.



VIDEO 15.1 Step-by-step femoral arterial line insertion.

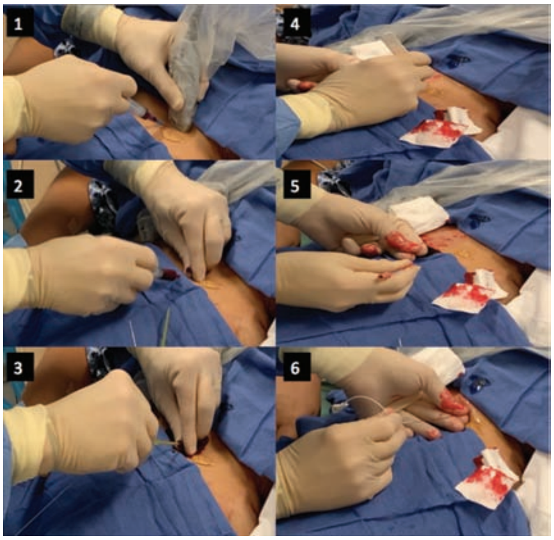


FIGURE 15.8 Sequential steps of femoral arterial line insertion. 1) Center needle and transducer over femoral artery. 2) Aspirate blood. 3) Insert guide wire. 4) Remove needle. 5) Dilate skin as needed with a twisting motion nearest to the skin. 6) Insert catheter over guide wire. Remove guide wire and connect monitor. Suture catheter in place. Apply sterile dressing. *Maintain contact with the guide wire at all times.

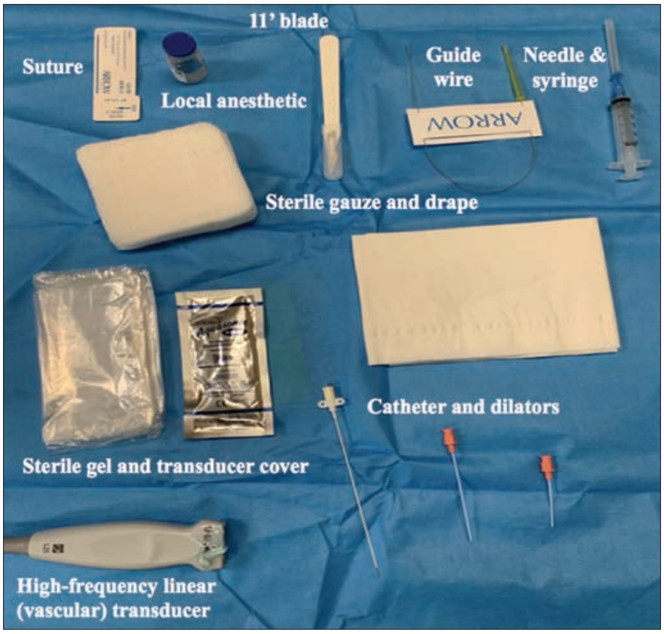
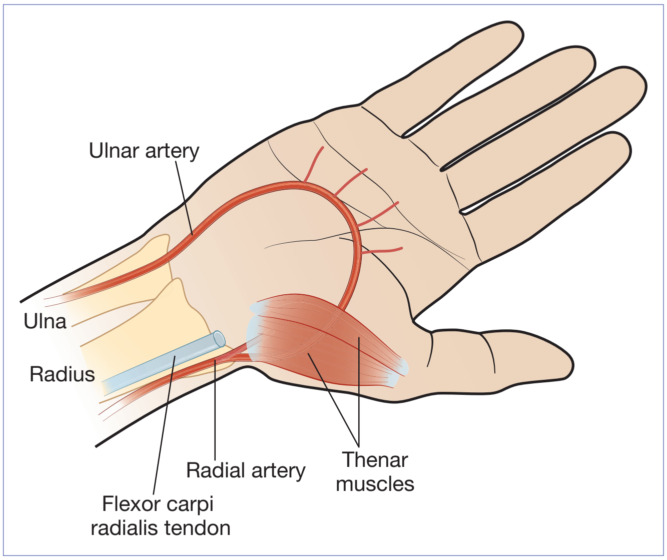

11' blade
Suture
Local anesthetic
Guide wire
Needle & syringe
ARROW
Sterile gauze and drape
Catheter and dilators
Sterile gel and transducer cover
High-frequency linear (vascular) transducer

FIGURE 15.9 Arterial line supplies. Note: Commercially prepared kits may vary.

Anatomic Locations

- Radial artery: Placed anatomically between flexor carpi radialis (FCR) and distal radius (**FIGURE 15.10**)
  - Nondominant hand
  - High-frequency linear transducer
  - Mildly hyperextend the wrist using a Kerlix or Ace wrap
    - Tape in place or have an assistant hold the hand
  - There is no benefit in applying a distal tourniquet for cannulation
    - Prospective, double-blinded, RCT
    - Single center study with $N = 240$ patients undergoing orthopedic surgery.
    - It may, however, help to palpate the artery if using the landmark technique.


Ulnar artery
Ulna
Radius
Radial artery
Thenar muscles
Flexor carpi radialis tendon

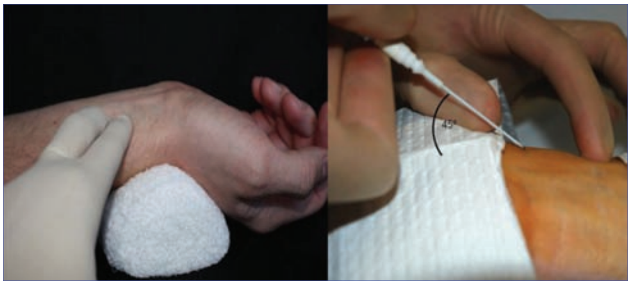


FIGURE 15.10 Radial arterial line anatomic landmarks.

- Common femoral artery (CFA): Anatomically moves from lateral to medial: femoral nerve → CFA (bifurcates into femoral artery and deep femoral artery) → common femoral vein → “empty” (femoral canal) → lacunar (or Gimbernat’s) ligament or lymphatics (NAVEL; **FIGURE 15.11**)
  - High-frequency linear transducer
    - Consider using a low-frequency curvilinear transducer for obese individuals.
  - Externally rotate the leg (frog-leg position).
    - Tape pannus or have someone retract it; skin must be taut.
  - Palpate the femoral artery just distal to the inguinal crease.
  - Do not cannulate the femoral artery or deep femoral artery.
    - Use the CFA as it is best for interventional procedures if need be at a later time; ECMO, cardiac catheterization, and/or intra-aortic balloon pump placement may also be used.
    - The femoral artery becomes the iliac artery as it ascends above the inguinal ligament; hence, arterial puncture must always occur distal to the ligament to prevent uncontrolled hemorrhage into the pelvis/peritoneum/retroperitoneum.
  - Despite clinical dogma, the infection rate is not higher than in peripheral sites with a low risk of infection (0.78%) and sepsis (0.44%).
- Axillary
  - Left is preferable to avoid air embolism.
  - Use a high-frequency linear transducer.
  - Use the hand-over-head position (**FIGURE 15.12**).
    - Hand is externally rotated and abducted to 90°.
  - Success rate for the experienced clinician is 99%. The rate for inexperienced clinicians was found to be 49% (*n* = 159) in a single-center retrospective study.

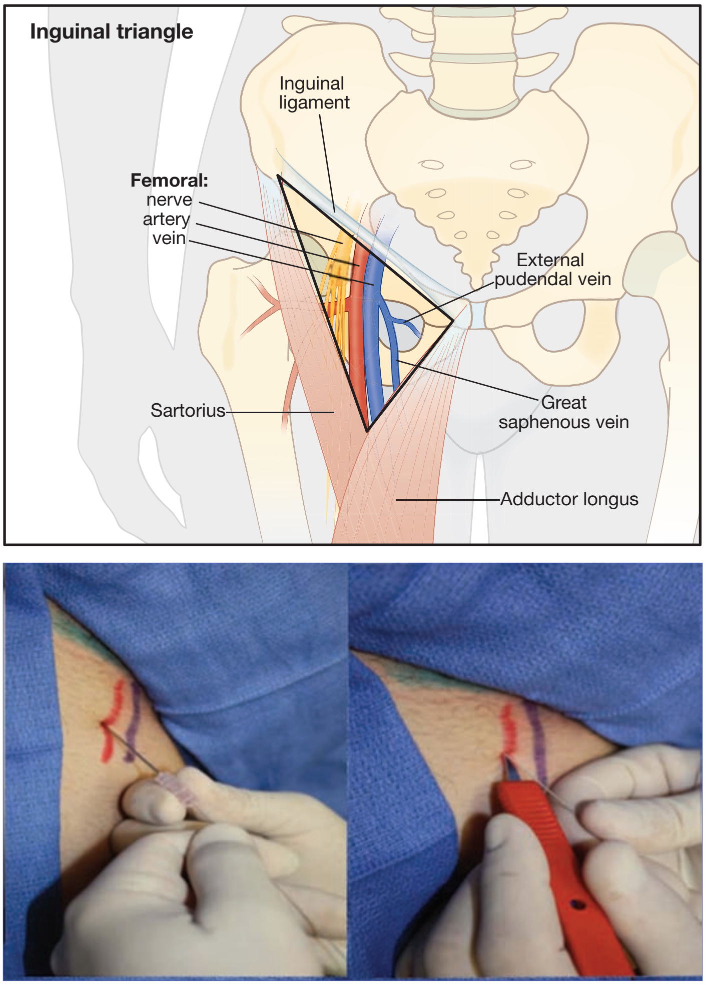


FIGURE 15.11 Femoral arterial line anatomic landmarks.

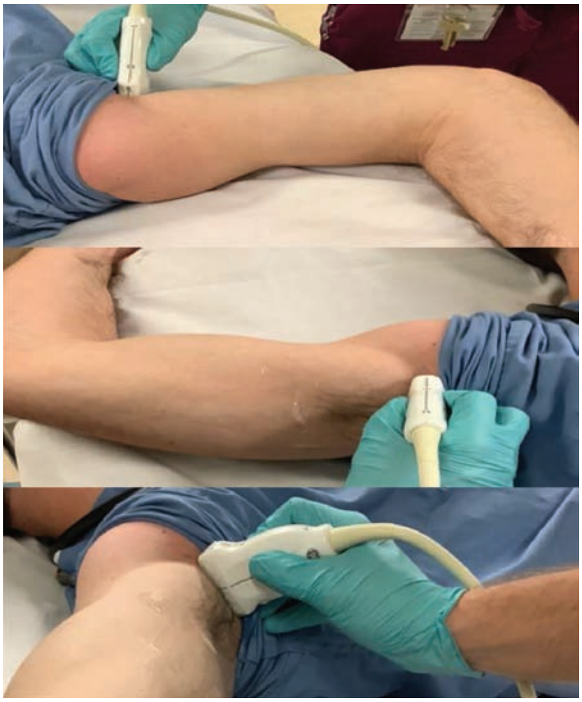


FIGURE 15.12 Upper extremity positioning for axillary arterial cannulation.

POSTPROCEDURE CONSIDERATIONS

- Apply firm pressure for 10 minutes or longer after removing a peripheral artery catheter and longer after femoral cannulation or if the patient is receiving anticoagulants.
- Troubleshooting
  - Inspect tubing and connections.
    - Confirm that there is no air in the system.
  - Ensure pressure bag is fully inflated to 300 mmHg.
  - Return the monitor to zero.
    - Confirm correct scale.
  - Confirm catheter placement with ultrasound.
  - Replace arterial line.
- Complications
  - Remove the line.
  - Begin antibiotics for infection.
  - Consult vascular surgeon for ischemic complications.

EDUCATIONAL POINTS

- It is preferable to use NIBP in the following patients:
  - Those who are clinically improving
  - Those who have achieved adequate perfusion
  - Those on a low-dose vasopressor
- ABGs are not clinically indicated routinely.
  - Utilize when SpO_2 is not available or in hemoglobinopathies.
  - VBG values correlate closely.
    - Not true in severe shock or cardiac arrest
  - $PaCO_2$ levels do not correlate well but trend together at greater than 45 mmHg.
- Central access is preferred (common femoral or left axillary) when utilizing invasive BP monitoring.
  - Bigger target and easier to access
  - Less painful
  - More accurate
  - More reliable
  - Similar complication rate
    - Infection rate less than 0.50%
  - Use for cardiopulmonary resuscitation, including ECMO
- Do not use end arteries (i.e., brachial).
- Use the nondominant hand if using peripheral artery.
- Employ sterile technique.
- There is no evidence to support the use of a distal tourniquet.
- A normal modified Allen's test does not predict ischemic complications.
  - If normal: low rate of ischemic complications
    - Remember to consider risk factors.
  - If abnormal (>5 seconds), use another location
- Ultrasound guidance is the standard of care.
  - Utilize dynamic needle-tip positioning.
  - Consider long axis.
  - Confirm wire and catheter placement.

COMPLICATIONS

- Review of arterial lines placed between 1978 and 2001:
  - 19,617 radial artery
  - 3,899 CFA
  - 1,989 axillary artery

- Major complications (<1%):
  - Vascular insufficiency (4%)
  - Permanent occlusion (0.09%) thrombosis, embolus
    - Temporary occlusions at the radial site usually recanalize.
    - Incidence decreases with a shorter duration of time.
      - Femoral (7 days)
      - Radial (4 days)
  - Pseudoaneurysm (0.09%) sepsis, rupture
  - Arteriovenous fistula
  - Nerve injury (median, brachial plexus)
    - Usually secondary to compression neuropathy
  - Compartment syndrome
  - Retroperitoneal bleed (one case report)
  - Infection and sepsis (0.13% radial; 0.44% CFA, 0.51% axillary)
    - The incidence of catheter-related infections increases over time.
    - With meticulous sterile technique, there is a negligible rate of infection in the first 96 hours after placement.
    - Literature has shown that changing the arterial catheter over a guide wire every 96 hours has fueled an infection rate of approximately 10% at both the radial and femoral sites.
- Minor complications:
  - Pain
  - Bleeding (2.1%)
  - Hematoma (14.4%)
  - Temporary occlusion/spasm (most common 1.5%–88%)
    - More likely with radial, CFA (1.18%)
  - Local infection
  - Carpal tunnel syndrome

PEARLS

- Femoral lines can generally be inserted faster among critically ill patients with hypotension and vasoconstriction; do not waste time fiddling around with radial arterial lines, delaying other critical interventions.
- Femoral arterial lines are more reliable over time and less likely to suddenly quit working.
- With good technique and ultrasonography, femoral arterial lines have a similar safety profile compared with radial arterial lines; the exception is coagulopathic patients in regards to potential retroperitoneal hemorrhage, whereas the radial site is easily compressible.
- Femoral arterial line is a bigger ultrasound target.
- Central arterial MAP is more accurate in the very sick patient.
- Even though it is in a larger vessel, the femoral arterial line shares the same complication rate as the radial arterial line.
- A positive Allen test result (abnormal) is indirect evidence suggestively implying inadequate collateralization (< 3% of population) and is defined as the continued presence of pallor longer than 5 seconds after release of the radial artery, although the accuracy of the test is poor.
- In comparison to the radial artery, the ulnar artery is smaller and is adjacent to the ulnar nerve; hence, it is not used.
- The peripheral brachial artery has no collateralization; therefore, it is not used.

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UNIT
VI

Managing Pain Using Injectable Anesthetics

CHAPTER

16

Anesthetic Agents and Procedures for Local and Field Infiltration

Nick Tyner, Jessica Genninger, and Keith Lafferty

BACKGROUND

The success rate of any procedure depends largely on the modulation of pain. Use of local anesthetic (LA) agents allows for regional and local pain control. Since cocaine was introduced as the first LA agent in the late 1800s, emergent procedures have progressed exponentially. In modern medicine, there are several types of LAs. An understanding of their basic principles is paramount in emergency medicine.

LAs reversibly block sodium channels in pain fibers, which are peripheral nerves that begin in the dermis and end at the spinal cord. These thin fibers have no myelin sheath and are susceptible to blockade by LAs. Neurons conduct an impulse by sodium influx via a gate, which results in depolarization of the cell membrane. The depolarization travels in a proximal direction. LAs, by either directly blocking sodium entry or by inducing swelling of the gate, do not allow depolarization. Therefore, no "pain" signal can travel to the spinal cord and hence to the brain (**FIGURE 16.1**).

Depending on the intermediate chain in their molecular composition, LAs are classified into two groups: amides and esters. Amides are used much more often and the discussion focuses on these. *A commonly taught mnemonic to remember which LAs are amides is that there is at least one "i" in the prefix before "caine."* The individual properties of each LA are a result of slight biochemical differences in their compositions. Esters include

- Cocaine
- Procaine
- Tetracaine
- Chloroprocaine
- Benzocaine

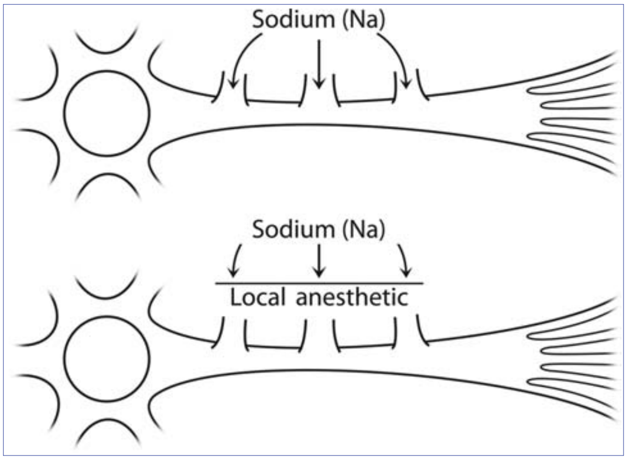

FIGURE 16.1 Neuron action potential; normal blockade with local anesthetic.

The main properties that must be considered when choosing an LA are potency, time of onset, and duration of action. The potency of an LA is determined by its liposolubility, as the cell membranes that interact with the sodium channels are mostly phospholipids. More lipophilic agents have a higher potency. Time of onset is determined by the pK_a, or the pH at which 50% of the drug is in its ionized form and 50% is nonionized. *Nonionized molecules diffuse more rapidly across lipid membranes, so if the pK_a is lower than the tissue pH, there will be more nonionized molecules available and therefore the drug will have a faster onset of action*. Sodium bicarbonate, which raises tissue pH, can be used as a buffering agent to shorten the onset of action of the LA. The duration of action of an LA is related to its receptor affinity (**see TABLE 16.1**).

TABLE 16.1 **Commonly Used Anesthetic Agents—Onset, Duration, and Maximum Dose**

Drug	Onset (minutes)	Duration (minutes)	Maximum Dose (mg/kg)
Procaine	15–20	40	7
Lidocaine			
Without epinephrine	2–5	30–120	4
With epinephrine	2–5	60–180	7
Bupivacaine			
Without epinephrine	10–15	200+	2
With epinephrine	10–15	200+	3
Mepivacaine	2–5	45–90	6
Ropivacaine	5–15	200+	3
Diphenhydramine	2–5	20–30	1.5

Toxicity

If large amounts of LAs are absorbed into circulation, systemic toxicity can occur. The central nervous system and cardiovascular (CV) system are particularly susceptible to LA's action and toxicity. Symptoms can range from subtle neurological symptoms to severe cardiac and neurologic instability. Although local anesthetic systemic toxicity (LAST) is rare, an understanding of the toxicity profiles of different LAs and how to treat LAST is necessary for any clinician using LAs. The uptake of LAs into circulation can occur from either:

- Accidental intravascular injection
- Absorption of local spread of high-volume injections

LAST typically presents with prodrome symptoms:

- Perioral numbness
- Tinnitus
- Alterations in mental status such as agitation or confusion

Signs of toxicity occur in a stepwise manner for the given organ system involved. ***CNS symptoms can progress to seizures and coma***. The signs and symptoms of CV toxicity range from hypertension and tachycardia to bradycardia and hypotension. This can progress to ventricular arrhythmias and asystole. ***The onset of symptoms typically occurs quickly, within a minute after injection***, but symptoms can manifest in a delayed fashion (greater than 1 hour).

Toxicity occurs in a dose-dependent manner and so close attention must be paid to the maximum weight-based dose, especially when using LAs for multiple separate procedures or high-volume nerve blocks. More lipophilic agents, such as bupivacaine, have an increased risk of toxicity. ***Because skeletal muscle acts as a depot for LAs, patients with limited muscle mass are at increased risk for toxicity***. Caution also should be taken in patients at extremes of age or with significant comorbidities, as baseline organ dysfunction can contribute to toxicity.

Currently, the mainstay of treatment for LAST is intravenous administration of a 20% lipid emulsion, although the literature is limited to case reports/series. Since 2006, there have been several case reports of successful treatment of LAST with this approach. The lipid emulsion acts as a "lipid sink" and scavenges the LAs in circulation and also acts directly on the heart to improve cardiac output. The American Society of Regional Anesthesia and Pain Medicine (ASRA) recommends 1.5 mL/kg bolus followed by a 0.25 mL/kg/min infusion at the earliest signs of toxicity (Gmyrek, 2019; McLeod, 2019; Mudarth & Kushelev, 2018).

In addition to lipid resuscitation therapy, seizures should be treated with intravenous (IV) benzodiazepines and standard advanced cardiac life support (ACLS) protocols should also be followed.

Allergies

Allergic reactions to LAs are very rare. ***Anaphylaxis is more common with esters such as tetracaine and benzocaine***. Reactions to preservatives in the formulations, such as methylparaben, can also occur. Signs and symptoms of LAST can be mistaken for immunologic reactions. However, if a patient reports a history of significant allergic reaction to an amide, an ester can be considered and vice versa. Diphenhydramine is also an LA that has been used extensively as an alternative to traditional amide and ester LAs. However, diphenhydramine is a local tissue irritant and there are reports of skin necrosis occurring with concentrated forms (2% and 5%). A more diluted preparation (1%) lowers the risk of necrosis. Systemic side effects, such as sedation and dizziness, can occur with more than 5 mL (50 mg) of diphenhydramine.

TREATMENT

LA for wound management is delivered via three different techniques:

- Topical anesthesia (TA)
- Infiltrative anesthesia
- Field-block anesthesia

Topical Anesthesia

Topical anesthetics are useful in many clinical scenarios and can be used alone or as adjuncts to other anesthetics. Though different agents and formulations may be used, intact skin, wounds, and mucous membranes are typically amenable to their application. Advantages of topical anesthetics include being easy to apply, pediatric friendly, and, unlike infiltrative anesthetics, they will not distort wound morphology.

- EMLA (prilocaine, lidocaine)
  - Useful on intact skin (abscesses, etc.).
  - Apply 60 minutes prior to procedure.
- LET (lidocaine, epinephrine, tetracaine)
  - Useful for open wounds, lacerations.
  - Apply for 20 to 30 minutes prior to wound manipulation.
  - As effective as TAC (tetracaine, adrenaline, cocaine), which has been replaced by less toxic preparations.
- Ethyl chloride and fluori-methane sprays
  - Vapor coolants: On topical application, the skin is cooled to −20°C, temporarily freezing the skin (less than 1 minute).
- Benzocaine
  - Use directly on mucous membranes as it is highly insoluble in water.

Infiltrative Anesthesia

Can be used in conjunction with topical anesthetics. It has rapid onset and is considered very safe when correct anesthetic dosages are used. Unless the wound is grossly contaminated, every attempt at injecting through wound margins should be made. This is less painful than injecting through the epidermis. To avoid excessive patient discomfort from multiple needle entries into the skin, attempt to tunnel the needle into the subcutaneous tissue, injecting with withdrawal. A 25- or 27-gauge needle should be used for patient comfort. Smaller-sized lumens may induce too much injection resistance and should be avoided.

Techniques to Reduce Pain

- Small-gauge needle (25, 27, or 30 gauge)
  - Arendt-Nielsen et al. (2009) have shown that the outer needle diameter was positively and significantly correlated to the frequency of the insertion pain:
    - 63%—23G
    - 53%—27G
    - 31%—32G
- Slow infiltration
  - Causes less distention of tissue
  - Perpendicular insertion into the skin
    - Martires et al. (2011) have shown that there was significantly less pain with injections done at 90° than those done at 45°.
  - Keep some visible anesthetic ahead of the needle's tip.
    - Almost always, pain after the first poke is caused by the needle tip hitting nerves that have not yet been anesthetized.
    - When moving laterally beneath the skin, it is important to keep 5 mLs of palpable or visible LA ahead of the tip; this anesthetizes the subdermal nerve endings.
- Warming fluid
  - Sultan (2007) has reviewed 11 papers studying the warming effect of an LA in regard to decreasing pain and has concluded that warmed LA solution is significantly less painful than that at room temperature.
  - Other literature has looked at warming to 40°C (104°F) with similar results.
- Buffered solution
  - With an acidic pH of 4.7, lidocaine can cause an unpleasant burning sensation.
  - A Cochrane meta-analysis of several randomized controlled trials (RCTs) determined that the addition of sodium bicarbonate (10:1 lidocaine: sodium bicarbonate [8.4% $NaHCO_3$]) can considerably minimize pain (Frank & Lalonde, 2012).

Field-Block Anesthesia

A surrounding wall of subcutaneous LA is placed in an area adjacent to the wound. This can be used in areas such as the ear, where infiltrative anesthesia would be an anatomical challenge. This may also be used in largely contaminated wounds. Pain from multiple needle sticks through the skin can be mitigated by administration of subsequent LA through previously anesthetized areas.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Allergy to a specific anesthetic agent may require consideration of other agents to be used.

PROCEDURE PREPARATION

In order not to exceed maximal dose of anesthetic, calculate this number prior to procedure. ***A quick method for converting any LA percentage into its concentration is to add a zero after the numerical percentage and then erase the "%"—so a 1% solution is 10 mg/mL.***

- Arrange patient in comfortable position that provides adequate anatomical access to the field.
- Anesthetize field prior to irrigating wound.

Topical Anesthesia

- Gloves
- Sterile cotton ball or gauze
- LET (lidocaine 4%, epinephrine 0.1%, tetracaine 0.5%)

Infiltrative Anesthesia and Field-Block Anesthesia

- Gloves
- Skin cleanser
- LA
- Syringe
- 25- or 27-gauge needle

PROCEDURE

Topical Anesthesia

- Remove gross decontaminants.
- Soak cotton ball or gauze and sprinkle drops over the wound.
- Apply anesthetic with an occlusive dressing.
- Allow at least 30 minutes for effect.
- In the case of intact skin and use of EMLA, allow 60 minutes for drug to take effect.

Infiltrative Anesthesia

- Direct the needle into the wound margin just below the dermis at the level of the superficial fascia (**FIGURE 16.2**).
- Insert the needle two-thirds of its length and advance in a direction that is parallel to the wound edge.
- Inject the LA upon slow withdrawal of the needle.
- Repeat this step in an area where the LA was previously deposited.

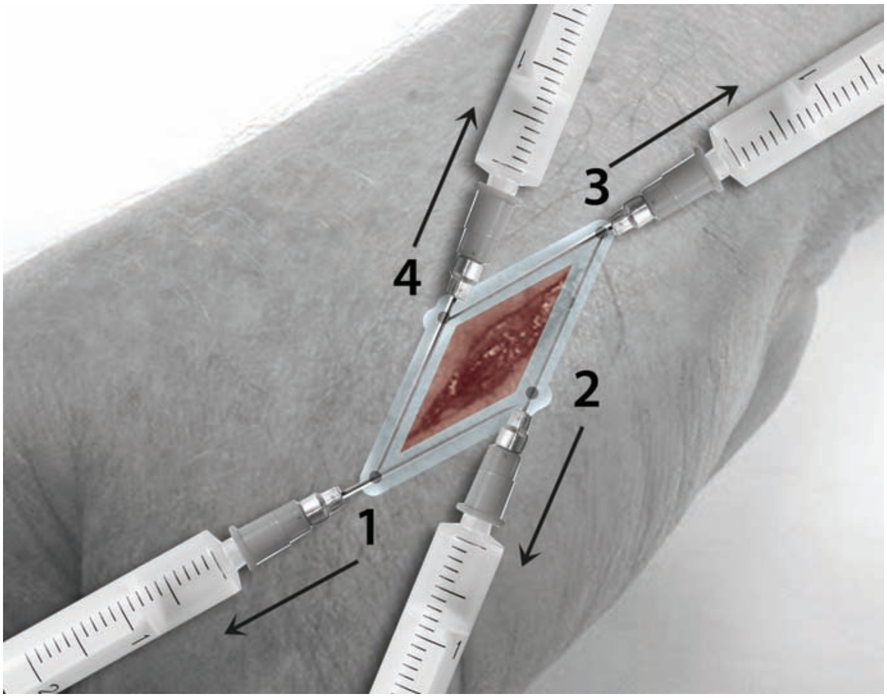

FIGURE 16.2 Infiltrative anesthesia technique.

Field-Block Anesthesia

- Insert the needle 1 cm away from the wound or structure through the epidermis to the level of the subcutaneous tissue.
- Insert the needle two-thirds of its length and advance in a direction that is parallel to the wound edge.
- Inject the LA upon slow withdrawal of the needle.

- Continue repetition of the previous step until a wall of LA is deposited around the wound or a diamond shape surrounds the structure (e.g., when applying to the ear).
- Repeated injections should be placed in an area where the LA was previously deposited (**FIGURE 16.3**).

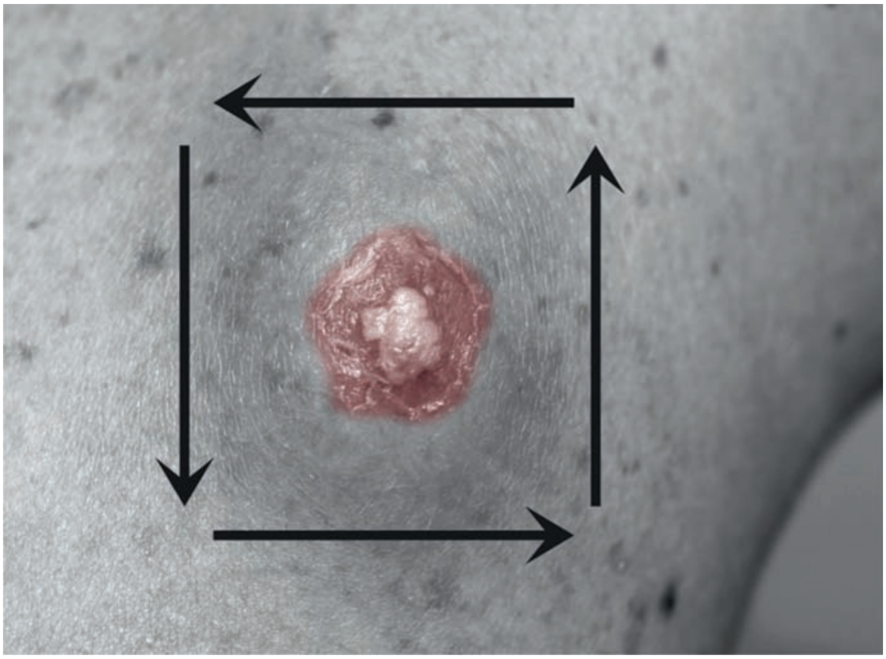

FIGURE 16.3 Field-block anesthesia technique.

POSTPROCEDURE CONSIDERATIONS

- Bleeding
- Pain at injection site(s)

COMPLICATIONS

- Infection
- Bleeding
- CV toxicity
- CNS toxicity
- Vasovagal syncope

PEARLS

- Bupivacaine lasts much longer than lidocaine but has higher risks of toxicity; these are negligible in common procedures.
- True allergic reaction consists of urticaria, pruritis, wheezing, and so on, and not vasovagal symptoms.
- Esters (less utilized) are more toxic than amides (more utilized).
- Use LA liberally, even in wounds without a closure, as there is no reason to inflict unnecessary pain on patients.
- Injection through the wound edges is less painful than through the epidermis.
- Topical agents are well tolerated and effective in children.
- Though most cases of systemic toxicity are caused by inadvertent intravenous injection, calculate the maximal dose for large wounds.
- To convert any LA percentage to its concentration, add a zero after the numerical percentage and erase the "%"—a 1% solution is 10 mg/mL.

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CHAPTER

17

Regional Anesthesia With Ultrasound Guidance

Jessica Genninger and Nick Tyner

BACKGROUND

Regional anesthesia is the technique of providing anesthesia to a targeted region of the body via nerve blockade. This method of anesthesia delivery can offer specific advantages over a general approach, which utilizes systemic medications, or the local approach in which an anesthetic agent is delivered directly into the target tissues. Regional anesthesia can be achieved by ultrasound-guided nerve blocks (UGNBs). UGNBs are a valuable tool in the kit of emergency medicine (EM) pain management and procedural skills.

Via a UGNB, pain receptors are targeted "mid stream" between the central nervous system and the target area. Thus, the clinician can achieve a greater general area of anesthesia compared to a local approach, anesthetize areas that are difficult to locally reach (i.e., a hip joint), avoid the use of systemic medications with significant side effect profiles or toxicity, and avoid injecting local anesthetic (LA) into vasculature or where it may cause cosmetic distortion of the wound. UGNBs are safe, well-tolerated, and efficacious.

ANATOMY OF PERIPHERAL NERVES

In the periphery of the body, nerves travel within fascial layers, or planes. These fascial planes typically exist between muscles or between a muscle and soft tissue. As the muscles in the periphery contract and relax, peripheral nerves (**FIGURE 17.1**) glide between muscles, protected by their fascial layers. Peripheral nerves are easily identified on ultrasound by their classic hyperechoic-dotted appearances, often described as honeycomb-like.

These fascial planes are utilized to deliver LA to a nerve. By injecting LA within a fascial plane near a nerve, it passively spreads to and around the nerve and diffuses across the protective sheaths around the nerve bundles

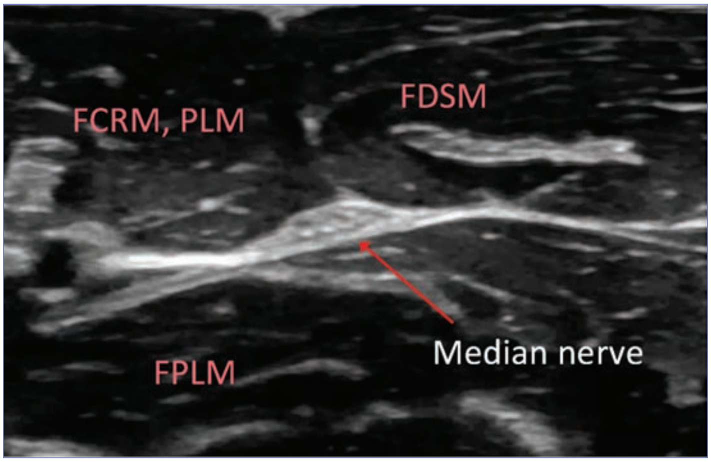


FIGURE 17.1 The median nerve visualized in short-axis view at the mid-forearm.

FCRM, flexor carpi radialis muscle; FDSM, flexor digitorum superficialis muscle; FPLM, flexor palmaris longus muscle; PLM, palmaris longus muscle.

(epineurium and perineurium layers). The LA will then act on target receptors on the nerve axons. The goal is to insert the needle tip into the space between the fascial layers just next to or encircling the nerve and never into the nerve itself, which can cause edema and swelling within the nerve and potentially lead to neuron necrosis.

Once the anesthetic is injected, "hydrodissection" of the fascial plane away from the nerve is observed on ultrasound (**FIGURE 17.2**). The top, brightwhite echogenic fascial layer lifts up as the fluid accumulates between the layers, filling a potential space. The fluid then encircles the nerve, either circumferentially or in a crescent shape, either of which indicates fluid is in the correct anatomical location for the block.

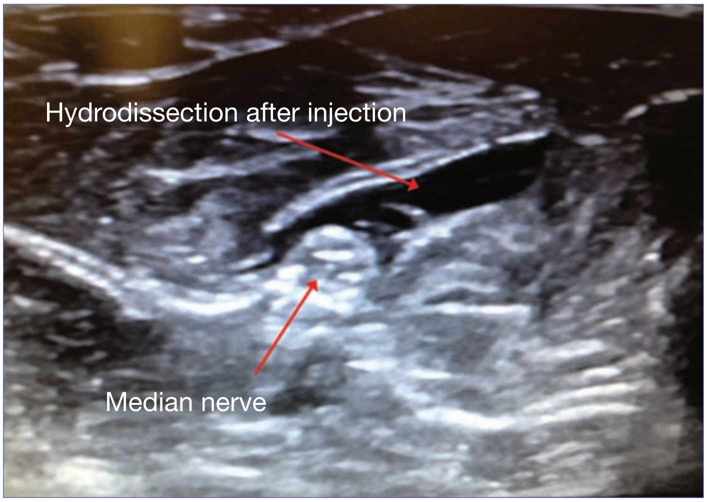


FIGURE 17.2 Anesthetic appropriately injected between the fascial layers binding a peripheral nerve will separate the fascial layers and either partially or fully encircle the nerve, leading to its blockade, as demonstrated by a median nerve block.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Severe allergy to LA is a contraindication to this procedure.

PROCEDURE PREPARATION

Equipment used for all UGNBs includes the following:

- Needle, 20 to 25 gauge for injection of LA, of appropriate length to reach the target nerve/fascial plane
  - Blunt-tip or short-bevel UGNB needles are theoretically ideal to minimize risk of nerve injury, although data is lacking.
  - Quincke spinal needles, readily available in most EDs, can be used as they have a shorter bevel than cutting needles.
  - If available, echogenic needles, which are coated with a polymer that improves needle visibility on ultrasound, can be helpful.
- Needle, 18 gauge for drawing up LA from vial
- Syringe for LA
- Sterile probe cover and sterile ultrasound gel
- Marking pen
- Sterile gloves
- Antiseptic solution
- LA

Note that nerve stimulators, commonly used by anesthesiologists, are not necessary in the ED.

These are the steps that should be taken prior to every UGNB. The sections that follow focus on additional block-specific steps.

- Prep patient in standard, aseptic fashion.
- Place probe in nondominant hand.
- Mark area and disinfect skin.

- Appropriately anesthetize the surface of the skin with quick-onset, short-acting anesthetic.
- Aspirate prior to instillation of solution in order to minimize risk of inadvertent injection into vessels.
- Do not apply pressure with the probe during injection.

Choice of Anesthesia

Shorter-acting LAs, such as lidocaine, can be used for brief bedside procedures. For longer acting pain control, LAs such as bupivacaine or ropivacaine, can be utilized. By decreasing systemic absorption, the addition of a vasoconstrictor, such as epinephrine, will prolong the duration blockade by as much as 50% (see Chapter 16 for more details).

Consider that the sensory and motor neurologic function of the targeted nerve is temporarily affected during blockade. For example, a radial UGNB performed in the supracondylar region results in a wrist-drop (motor blockade) in addition to sensory blockade. If a prolonged loss of motor function is undesirable, a shorter acting LA should be selected. The patient should be counseled on the length of action of the chosen anesthetic.

Mixing LAs to try to optimize a fast time of onset with long duration, although common practice, is not recommended. There is no data suggesting that it actually does improve time of onset and can significantly shorten the duration of blockade.

For peripheral UGNBs, a volume of 4–5 mL is typically sufficient. For field blocks, such as fascia iliaca, a larger volume (30–40 mL) is necessary. See the following text on individual blocks for more information.

There are many UGNBs that can be utilized to great effect in the ED. Describing every UGNB is beyond the scope of this book. Focusing on the most useful applications in EM, we first discuss two commonly utilized large-volume plane blocks: the fascia iliaca block (FIB) and the serratus anterior block. We then describe the technique for targeted UGNBs of several peripheral nerves: the forearm (median, ulnar, radial) nerves, the suprascapular nerve, and the posterior tibial nerve.

ULTRASOUND GUIDANCE

Probe Choice

Almost all UGNBs should be performed with a high-frequency linear probe for optimal visualization of the nerve and surrounding structures.

Ultrasound Technique

UGNBs can be performed utilizing an “out-of plane” or “in-plane” approach. The “in-plane” technique is preferable for most UGNBs because the tip of the needle is always in view, which theoretically minimizes the risk of passing the target or inserting the needle into a neuron fascicle or nearby artery. Although this technique can initially seem difficult to master, as the probe must be carefully aligned with the needle and even small probe movements can result in temporary loss of visualization of the needle, proficiency can be achieved with minimal practice and experience. In general, the nondominant hand holds the probe and the dominant hand directs the needle.

COMPLICATIONS

Complications associated with UGNB are often specific to the local anatomy of the procedure. For this reason, complications unique to each UGNB have been included in the section describing that particular block. A feared complication of UGNBs is systemic toxicity associated with toxic doses of LA, known as *local anesthetic systemic toxicity* (LAST; see Chapter 16).

Other complications include inadvertent arterial puncture and injection of LAs and damage to surrounding structures or the nerve itself, hematoma formation, and excess pain caused to the patient. As a general rule, LA should never be injected if there is a tactile feedback of increased resistance as this may indicate intraneural injection. The hand holding the probe should take care to release any downward pressure it is applying with the probe to minimize tension.

These complications can be mitigated by meticulous preprocedure planning, thorough knowledge of the anatomy of the unique UGNB being performed, and familiarity with the mechanics involved with ultrasound-guided procedures involving sharps. Development of the requisite motor skills needed is imperative to a successful and safe procedure.

FASCIA ILIACA BLOCK

BACKGROUND

The FIB is sometimes referred to as a three-in-one block as it targets the femoral nerve, lateral cutaneous nerve, and (unreliably) the obturator nerve with one injection in the inguinal region. The FIB is considered a safer alternative to femoral UGNBs, as the site of injection is more remote from the femoral vessels, which minimizes the risk of intravascular injection. The fascia iliaca is a fascial layer located anterior to the iliacus muscle. Moving laterally, it travels underneath the more anterior sartorius muscle. Both the femoral and lateral cutaneous nerves travel under the fascia iliaca. If a large amount of anesthetic (30–40 mL) is injected under the fascia, it will spread in both a lateral and medial direction and will reach these nerves. The FIB results in 100% blockade of the femoral nerve and 80% to 100% of the lateral femoral cutaneous nerve. It rarely blocks the obturator nerve.

The FIB block provides analgesia to the skin and muscles of the anterior thigh as well as most of the femur and knee. Its most important use in EM is for fractures of the femoral neck, which receives the majority of its sensory innervation from the femoral nerve.

PATIENT PRESENTATION

A 78-year-old female presents to the ED with left hip pain after a fall from standing. Her left leg is shortened and externally rotated. Imaging confirms a femoral neck fracture.

TREATMENT

The treatment plan for femoral neck fractures typically consists of operative intervention. In the ED, an early FIB can provide preoperative analgesia and help minimize the use of opioid pain medicine.

SPECIAL CONSIDERATIONS

A large-volume long-acting, dilute anesthetic is used in the FIB. The clinician should calculate the weight-based toxic dose of the chosen anesthetic and ensure that the dose administered is less than this toxic dose. The clinician should be familiar with the diagnosis and treatment of LAST (see Chapter 16 for more details).

PROCEDURE PREPARATION

Specific equipment for FIB includes the following:

- Needle, 8–10 cm, 22-gauge, ideally short bevel
- Tubing to connect the needle to the syringe [intravenous (IV) tubing can be utilized if the needle does not have built-in tubing]
- 30 to 40 mL of dilute anesthetic such as 0.25% bupivacaine

PROCEDURE

- Place patient in supine position with the bed flattened.
- Holding the probe just distal to the inguinal ligament (**FIGURE 17.3**), identify the femoral neurovascular bundle in the short axis (**FIGURE 17.4**) with the superficial fascia lata and the deeper fascia iliaca overlying the iliacus muscle.
- Slide the probe laterally away from the neurovascular bundle to identify the sartorius muscle (**FIGURE 17.5**).
- Align the needle with the lateral edge of the probe and insert the needle in an in-plane fashion several centimeters to the neurovascular bundle, directed medially.

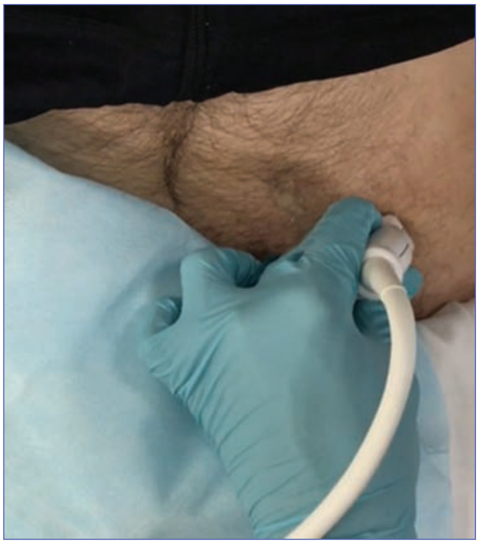


FIGURE 17.3 The high-frequency linear probe is placed distal to the inguinal ligament in the short-axis plane to visualize the femoral neurovascular bundle.

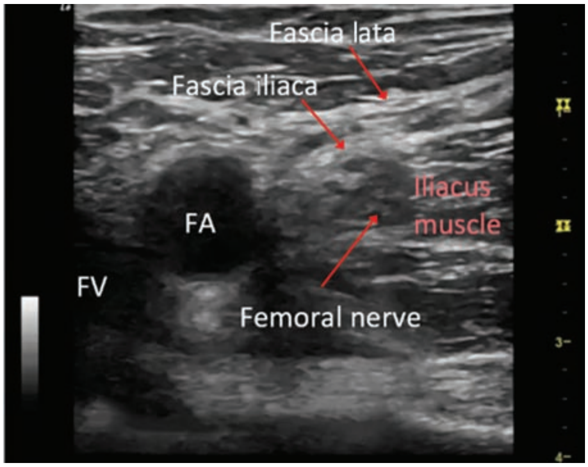

Fascia lata
Fascia iliaca
Iliacus muscle
FA
FV
Femoral nerve
3-
4-

FIGURE 17.4 The anatomy of the right fascia iliaca as visualized in the short-axis view in the medial inguinal region.

FA, femoral artery; FV, femoral vein.

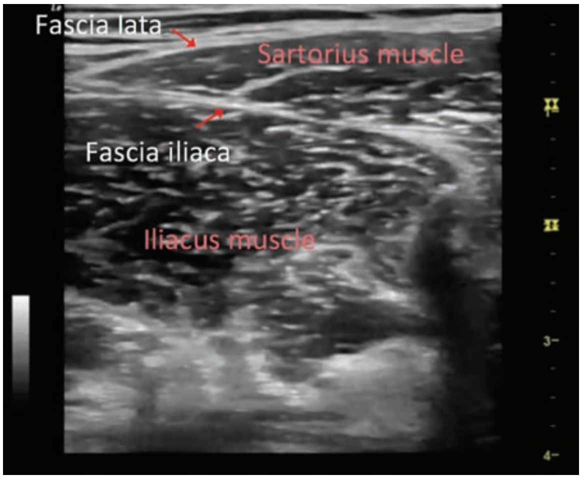

Fascia lata
Sartorius muscle
Fascia iliaca
Iliacus muscle
3-
4-

FIGURE 17.5 The anatomy of the right fascia iliaca as visualized in the short-axis view in the lateral inguinal region. This view is obtained from sliding the probe laterally from the view visualized in **FIGURE 17.4**.

- You may feel a tactile "double pop" as the needle tip passes through first the fascia lata and then, transversing the sartorius muscle, it will pass through the fascia iliaca.
- The goal is to place the needle tip just under the fascia iliaca several centimeters lateral to the neurovascular bundle (**FIGURE 17.6; VIDEO 17.1**)
- Connect syringe to needle via IV tubing and, if possible, have an assistant push the anesthetic when directed, so the clinician can keep one hand on the probe and the other on the needle.

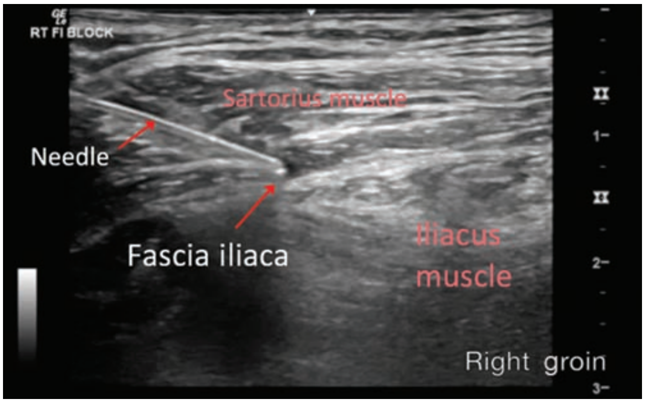
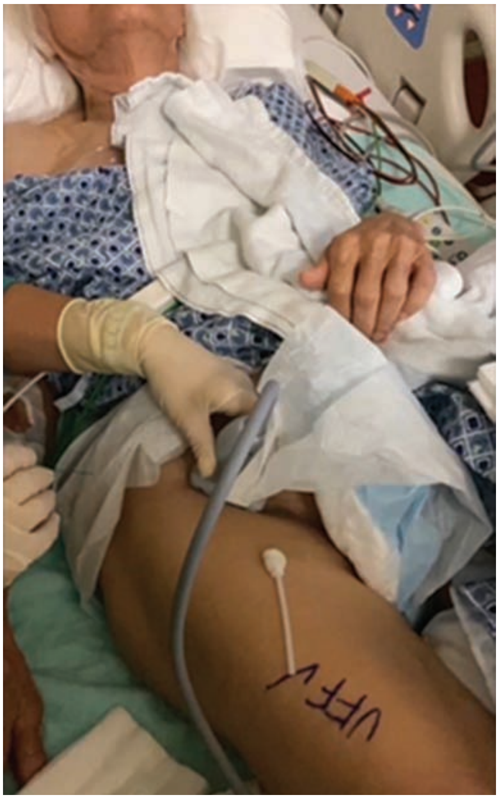

RT FI BLOCK
Sartorius muscle
Needle
Fascia iliaca
Iliacus muscle
Right groin
1-
2-
3-

FIGURE 17.6 The needle is inserted several centimeters lateral to the femoral nerve in the long-plane axis. Here the needle tip is visualized on top of the fascia lata just prior to "popping" through.



VIDEO 17.1 Fascia Iliaca block.

- As you inject, watch for separation of the fascia iliaca off of the iliopsoas muscle (**FIGURE 17.7**)—if it starts to accumulate intramuscularly, adjust the needle.
- The anesthetic should spread in a medial and lateral direction along the fascial plane, which can be confirmed by sliding the probe medially to identify a buildup of anesthetic around the femoral nerve (**FIGURE 17.8**).

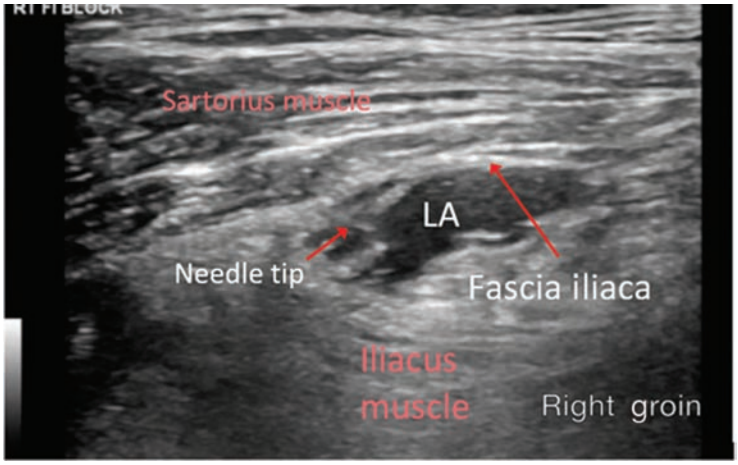


FIGURE 17.7 As the LA is injected, it separates the fascia iliaca above the iliacus muscle. Here it is visualized spreading medially from the site of injection toward the femoral nerve.

LA, local anesthetic.

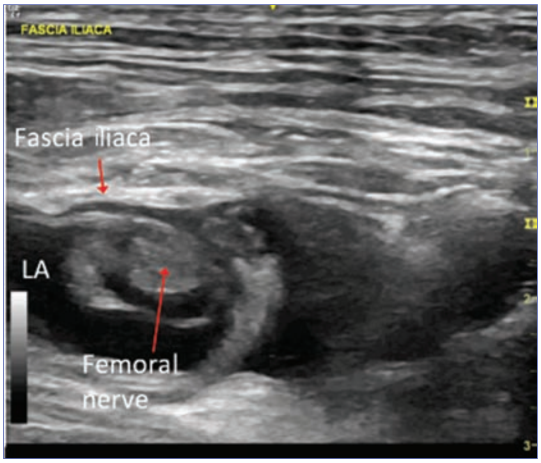


FIGURE 17.8 After injection of the LA, the probe can be slid medially to confirm appropriate spread of the LA to the femoral nerve.

LA, local anesthetic.

POSTPROCEDURE CONSIDERATIONS

- Keep in mind that the femoral nerve also supplies motor function to the quadricep muscle and its blockade may result in motor weakness.
- The patient should be closely monitored for any signs of LAST.

PEARLS

- Utilizing a second clinician or assistant to push the anesthetic, which can be connected to the needle via tubing, allows for better control of needle tip.
- Choosing a needle with a shorter bevel enhances the tactile feedback of the “pop” as the needle passes through fascia.

SERRATUS ANTERIOR BLOCK

BACKGROUND

Initially used to provide anesthesia during breast and chest wall surgeries, the serratus anterior block has become a useful adjunct in the treatment of emergency complaints such as rib fractures and other chest-wall trauma. Chest-wall trauma is a common ED complaint and is often associated with marked pain, as well as loss of productivity.

Pain control in relation to rib fractures has long-term beneficial value in terms of healing and decreased morbidity due to complications with impaired respiration. With knowledge of the local anatomy and ultrasound guidance, control of pain associated with single or multiple rib fractures can often be achieved.

PATIENT PRESENTATION

A 40-year-old male presents to the ED after an assault. He is complaining of pain in his chest where he reports being repeatedly kicked. Two nondisplaced rib fractures are confirmed on imaging, with no other complicating factors present.

TREATMENT

The treatment plan for rib fractures primarily consists of aggressive pain control in order to reduce the incidence of complications associated with long-term hypoventilation.

SPECIAL CONSIDERATIONS

It is important to have knowledge of the relevant chest anatomy. The lungs lie deep within the area in which this block is performed, which makes anatomical knowledge and mechanical ability especially important. The capacity to introduce a needle, under ultrasound guidance, into the correct tissue plane is imperative.

PROCEDURE PREPARATION

Specific equipment for serratus anterior block includes the following:

- Needle, 4 cm, 22 gauge, ideally short bevel
- 30 to 40 mL of dilute LA

PROCEDURE

- Place patient in lateral decubitus position.
- Locate the fifth rib in the mid to posterior axillary line, using the nipple line as a landmark (**FIGURE 17.9**).
- Place the probe over the fifth rib and identify the latissimus dorsi (LD) muscle overlying the serratus anterior above the fifth rib (**FIGURES 17.10** and **17.11**).
- Employ an in-plane anterior-to-posterior approach in order to visualize the needle tip and to direct the needle to an area just superficial to the serratus anterior (SA) muscle (**FIGURE 17.12**).
- Take extreme care to visualize the tip of your needle for the entirety of its trajectory, as extending deep to rib can puncture the pleura and cause a pneumothorax.

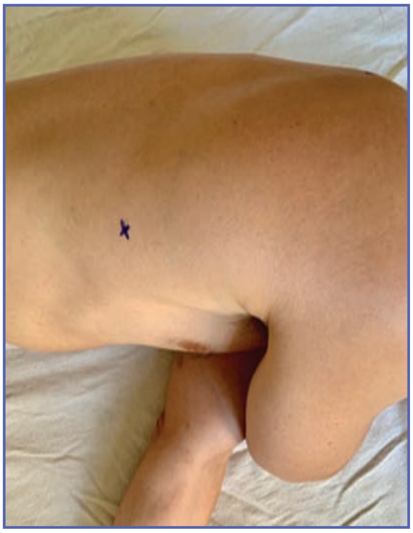


FIGURE 17.9 In the posterior axillary line, at approximately parallel to the nipple lies the posterior aspect of the fifth rib. The mark is directly over the tail of the latissimus dorsi, which lies superficial to the serratus anterior and the fifth rib.

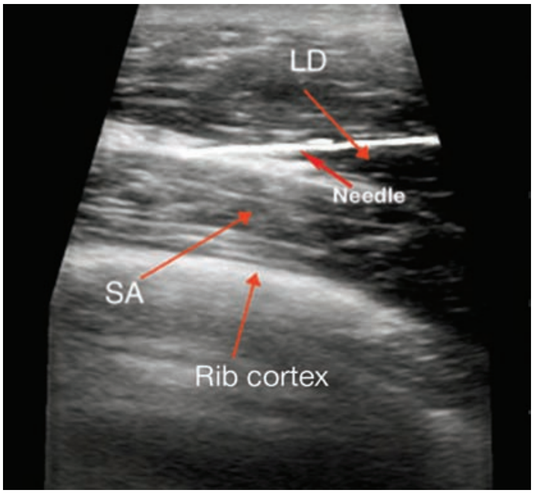


FIGURE 17.10 Ultrasound image of the target of the SA block. Note the LD attaching in the upper right of the image above the SA. Target for anesthesia is immediately below the fascial plane of the SA.

LD, latissimus dorsi; SA, serratus anterior.

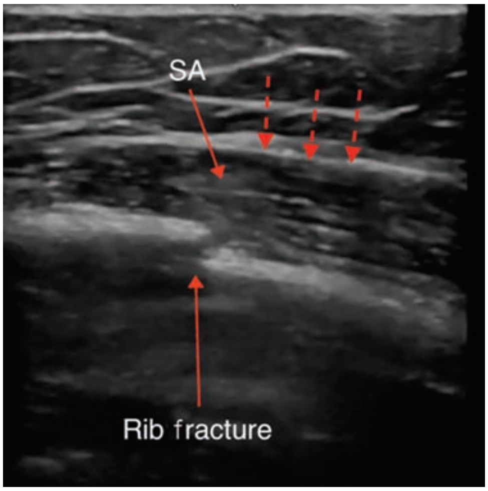


FIGURE 17.11 Broken rib. Target for anesthesia is just superficial to the SA muscles, but deep to the fascial plane (*dashed arrows*).

SA, serratus anterior.

- Inject the LA in a controlled fashion.
- Visualize the injection process, taking care that you are injecting the LA deep to the fascial plane, but not into the SA muscle proper (**FIGURE 17.13**).
- You should see a separating of the fascial planes as the LA infuses.
- As the LA moves along the plane of the SA muscle, your patient should now begin to have decreased motor and sensory sensation along the hemithorax.

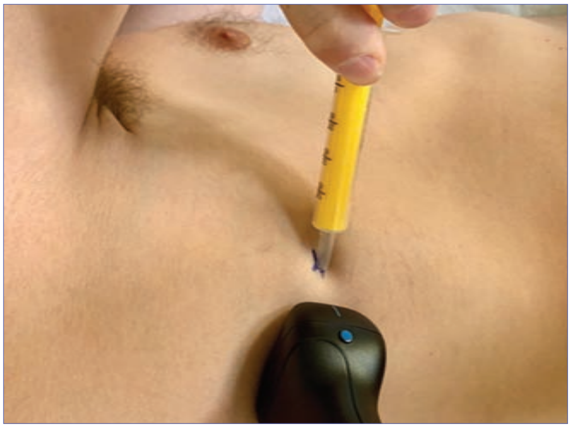


FIGURE 17.12 Approximate location and angle of needle when performing this block.

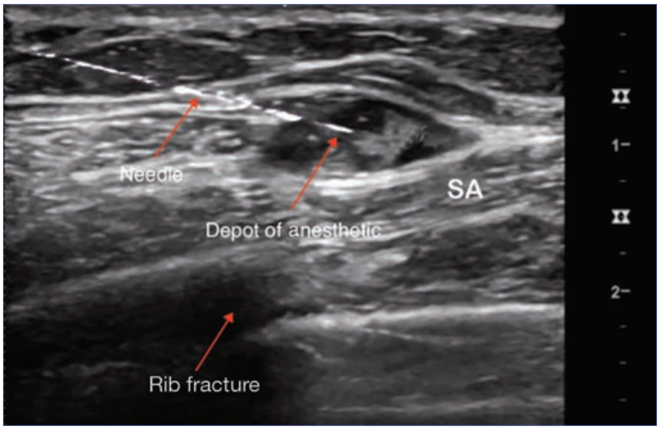


FIGURE 17.13 Example of correct placement of anesthesia with respect to the anatomy of the SA nerve block. Note the collection of anesthetic just deep to the fascial plane of the muscle.

SA, serratus anterior.

POSTPROCEDURE CONSIDERATIONS

- Check for lung sliding using the linear ultrasound probe to ensure that the lung pleura has not been inadvertently pierced during the procedure.
- When used with a long-acting LA, this block has been shown to have a duration of action in excess of 12 hours. Educate the patient accordingly.

PEARLS

- This is a plane block that, when done properly, allows anesthetic to diffuse throughout the area occupied by the SA, targeting the lateral cutaneous branches of the intercostal nerves and providing anesthesia from T2 to T9.
- Use an in-plane needle approach and use small aliquots of solution in order to visualize the path of your needle at all times.
- For most patients, this will be a relatively superficial block. You should plan on only needing to advance your needle a few centimeters.

SUPRASCAPULAR NERVE BLOCK

BACKGROUND

Suprascapular UGNB is useful in achieving anesthesia for common shoulder injuries. The nerve accounts for approximately 70% of the innervation to the glenohumeral joint, making it an important component when considering anesthesia to the area. Blockade of the nerve can also be used in chronic conditions, such as rotator cuff tendinitis, as well as the more emergent complaints seen in the ED, as in the case of shoulder dislocation.

PATIENT PRESENTATION

A 46-year-old female with left shoulder pain after a mechanical fall is unable to move the joint and is found to have an anterior shoulder dislocation.

TREATMENT

Timely reduction of the shoulder is the definitive treatment for this condition. Reduction can be challenging without adequate anesthesia. Suprascapular UGNB can be a useful adjunct in providing anesthesia, and ultimate success in reduction of the joint.

SPECIAL CONSIDERATIONS

It is important to have a working knowledge of chest anatomy with regard to ultrasound technology and the ability to introduce a needle under ultrasound guidance into the correct anatomical location. Review all pertinent anatomy and locate with ultrasound prior to injection of anesthetics.

PROCEDURE PREPARATION

Equipment for suprascapular UGNB includes the following:

- Needle, ~4 to 8 cm, 22 gauge, short bevel
- 10 mL of LA

PROCEDURE

- Position patient sitting upright.
- Identify the scapular spine (**FIGURE 17.14**) and place probe parallel to it (**FIGURE 17.15**).
- Identify the suprascapular nerve and artery beneath the transverse scapular ligament in the suprascapular notch. The nerve is usually hyperechoic with respect to surrounding tissues.

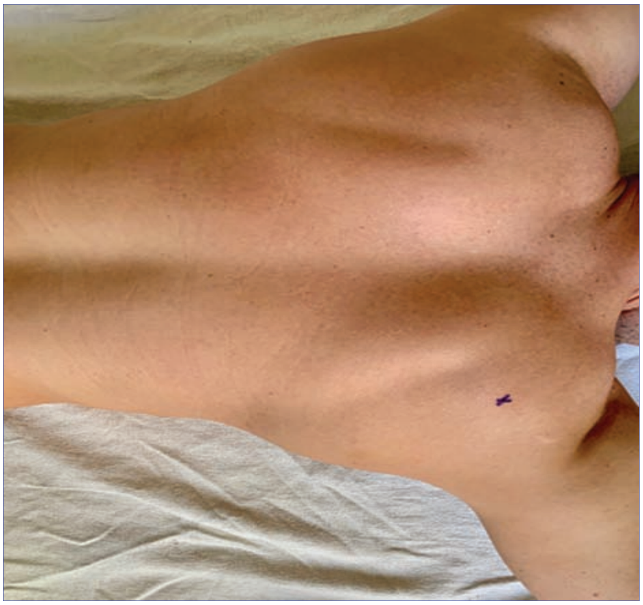


FIGURE 17.14 The spine of the scapula and the suprascapular notch underlies the mark on the skin and shows the approximate location for needle insertion.

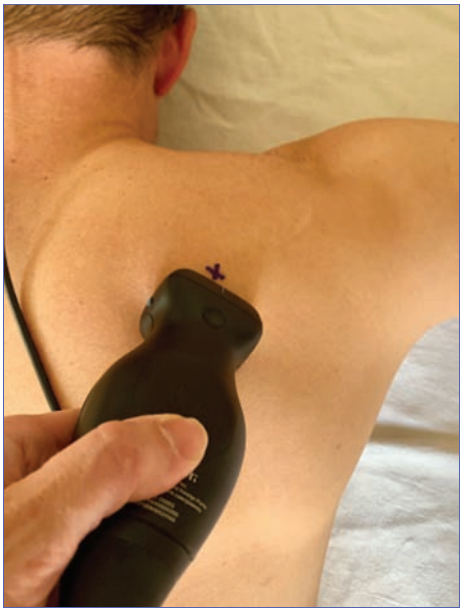


FIGURE 17.15 Approximate location of target with ultrasound probe abutting the scapular spine. Needle approach will be directed caudally, using the body of the scapula as a backstop against inadvertent entry into the thoracic cavity. Avoid directing your needle cephalad, as this could result in sliding behind the scapula and the aforementioned complication.

- Use color flow to identify the artery to avoid puncturing it (**FIGURE 17.16**).
- Using an in-plane approach, visualize your needle as it dissects the trapezius and supraspinatus muscles until it is directly adjacent to the suprascapular nerve (**FIGURE 17.17**).
- Inject 5 to 8 mL of LA.

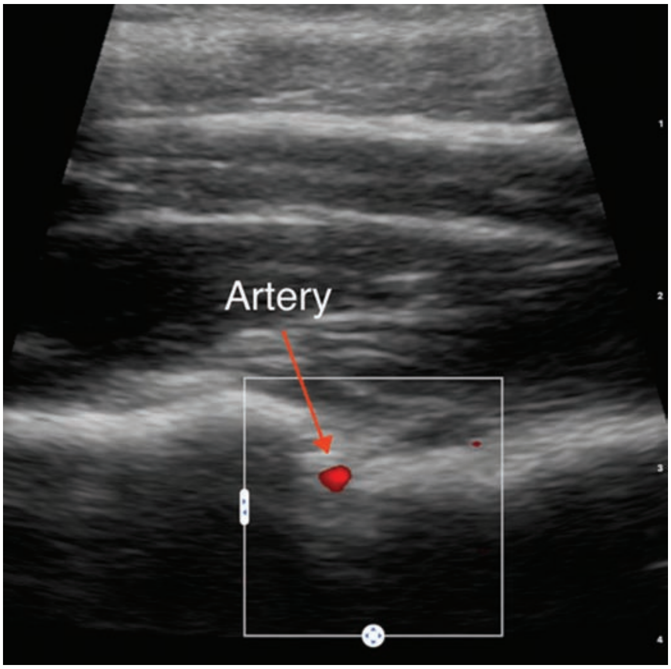


FIGURE 17.16 Ultrasound image using color flow to identify suprascapular artery.

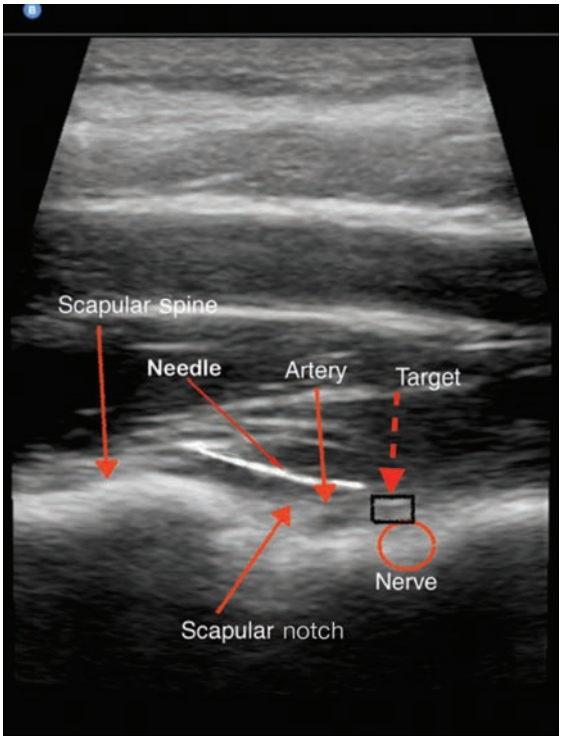


FIGURE 17.17 Ultrasound image of suprascapular anatomy. Inject anesthetic immediately adjacent to the nerve. Avoid injecting artery by visualizing lumen and active pulsations and aspirating prior to injection. Color flow Doppler can be utilized to visualize the artery. The rectangular box is the approximate target of the anesthetic.

POSTPROCEDURE CONSIDERATION

- Immediately check for lung sliding using your ultrasound probe to rule out an occult pneumothorax.

PEARLS

- The pleura of the lung lies immediately anterior to the suprascapular notch. Take care not to lose visualization of your needle tip, as pneumothorax is a potential complication.
- Use color flow to identify the neurovascular bundle.
- Keep in mind that you may not provide 100% anesthesia to the patient, as the suprascapular nerve only accounts for approximately 70% of the pain fibers to the shoulder.
- This can be used for awake reduction of shoulder dislocations.

POSTERIOR TIBIAL NERVE BLOCK

BACKGROUND

Providing anesthesia to the palmar surface of the foot can be an important tool in the ED. Foot injuries from stepping on sharp objects are a commonly encountered complaint. Posterior tibial UGNBs are ideal for procedures requiring anesthesia to the sole of the foot. The sensory component of the foot is complex and involves the coordination of multiple nerves, but the posterior tibial nerve is the only supply to most of the sole of the foot. Targeting the surrounding nerve bundle with LA is a relatively easy procedure owing to the nerve's superficial path posterior to the medial malleolus. Furthermore, using ultrasound as an adjunct has been shown to improve success rates in local anesthesia delivery due to the fact that the neurovascular bundle is easily identifiable to even the novice user.

PATIENT PRESENTATION

A 23-year-old intoxicated male presents with an 8-cm-jagged laceration to the sole of his midfoot after stepping on broken glass at the beach.

TREATMENT

Definitive treatment includes irrigation, exploration, and repair of the wound.

SPECIAL CONSIDERATIONS

The posterior tibial nerve travels closely with an artery at the site of injection, so care should be taken to visualize the needle tip during the entirety of the block, and aspiration before injection should always be performed.

PROCEDURE PREPARATION

Equipment for posterior tibial UGNBs includes the following:

- Needle, ~1.5 to 4 cm, 25 gauge, ideally short bevel
- 5 mL LA

PROCEDURE

- Place patient supine with knee slightly bent and foot externally rotated.
- Place the probe just proximal to the medial malleolus in the transverse plane (**FIGURE 17.18**).

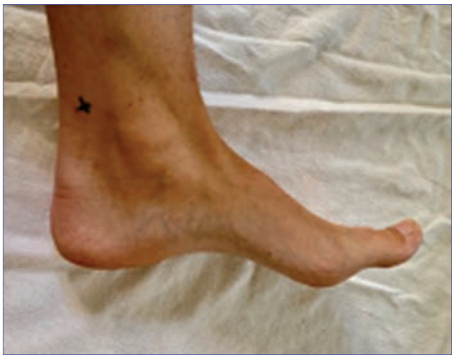


FIGURE 17.18 Approximate location of the posterior tibialis nerve. Note its location posterior to the medial malleolus.

- Identify the tibial artery, vein, and nerve. Color Doppler flow can assist if necessary. The nerve lies just posterior to the vessels (**FIGURE 17.19**).
- Using either an in-plane or out-of-plane technique to advance the needle, inject the LA deep to the fascia and directly adjacent to the nerve (**FIGURES 17.20** and **17.21** demonstrate an in-plane technique).

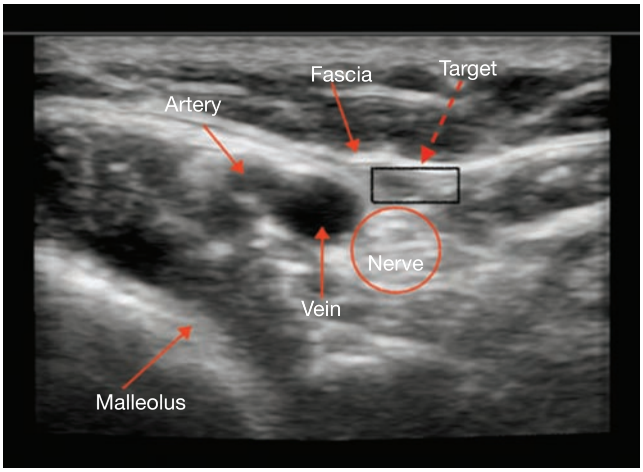


FIGURE 17.19 Ultrasound view of the posterior tibial neurovascular bundle in the transverse orientation as it traverses posterior to the medial malleolus. Deposit local anesthetic deep to the fascial plane and adjacent to the nerve fibers (approximate target is the box outlined in black).

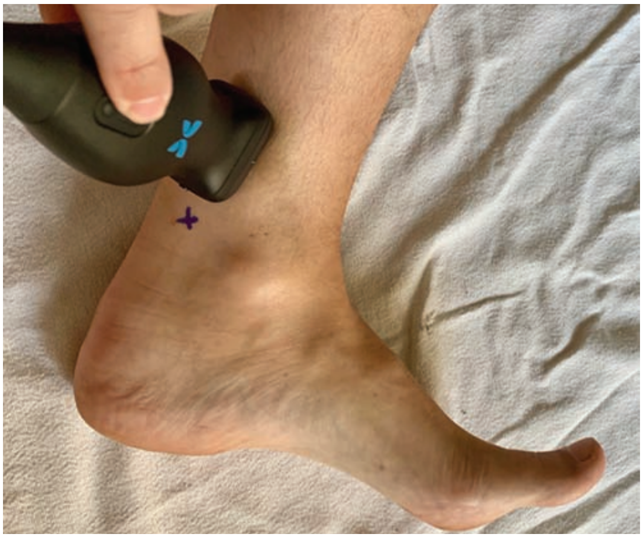


FIGURE 17.20 Identify the neurovascular bundle by employing a transverse orientation posterior to the medial malleolus. Slowly rotating on the nerve to a sagittal view will then allow you to approach the target nerve in-plane from below the probe.

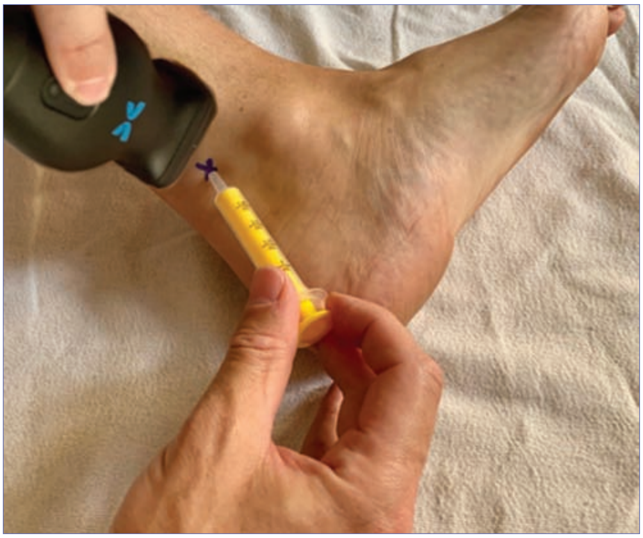


FIGURE 17.21 The neurovascular bundle runs relatively superficially. Angle your needle accordingly.

POSTPROCEDURE CONSIDERATION

- Anesthesia to the sole of the foot should occur rapidly if a short-acting LA is utilized.

PEARLS

- This block can be a useful adjunct to relief of pain in calcaneal fractures.
- The posterior tibial block can relieve the discomfort involved in foreign body removal, which is often a painful and laborious procedure.
- Take care to avoid injection into the artery as it travels in close proximity to the target nerve.

FOREARM NERVES: MEDIAN, RADIAL, AND ULNAR

BACKGROUND

Hand injuries and infections are commonly encountered complaints in the ED. Injecting local anesthesia directly into the skin and soft tissues of the hand can be very painful for the patient. Sensory innervation to the hand is supplied by the median, radial, and ulnar nerves (**FIGURE 17.22**), all of which can be targeted by blocks to the forearm. Blind UGNBs of these three nerves are frequently performed in EM. However, the forearm nerves are easily visualized on ultrasound and can easily and safely be targeted with ultrasound guidance, minimizing the risk of intravascular injection.

UGNBs can be used to provide anesthesia for lacerations, puncture wounds, abscesses, and fracture/dislocation reductions. The EP should target anesthetic choice to the individual case; for example, a shorter acting LA may be helpful in quick laceration repairs, whereas a longer acting anesthetic may be preferable for a fracture. If a small-gauge (i.e., 25-gauge) needle is chosen, there may be a higher risk of intraneural injection, so be cautious when injecting.

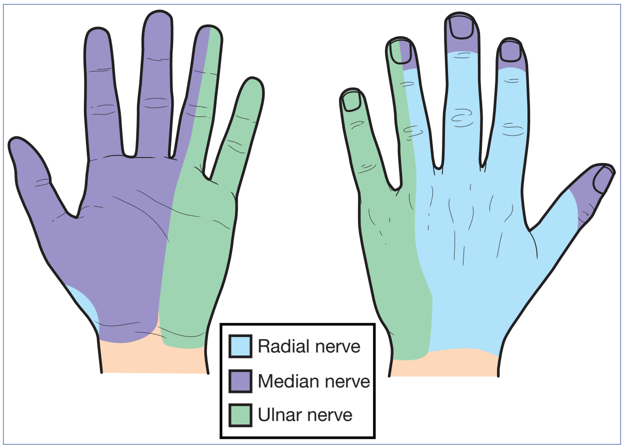


FIGURE 17.22 The sensory innervation of the hand.

PROCEDURE PREPARATION

- Needle, 22 to 25 gauge
- 4–5 mL of anesthetic

POSTPROCEDURE CONSIDERATIONS

- None

MEDIAN NERVE

PATIENT PRESENTATION

A 33-year-old male presents with a complex laceration to the thenar eminence sustained from an electrical saw while working on a construction project.

TREATMENT

The wound needs to be irrigated, explored, and repaired. A UGNB of the median nerve can be utilized for anesthesia.

SPECIAL CONSIDERATIONS

- None

PROCEDURE

- Place the patient's forearm on a procedure table or tray in supine position.
- Place the probe on the volar aspect of the arm in the transverse orientation just proximal to the wrist.
- The median nerve is located in the mid-forearm, about 1 to 2 cm medial and deep to the radial artery. It travels in fascial planes between muscles in the forearm.
- Slide the probe proximally (**FIGURE 17.23**) until the median nerve is easily visualized between the muscles, away from the distal tendons, which can be difficult to differentiate from nerves (**see FIGURE 17.1**).
- Insert the needle just adjacent to the nerve (**FIGURE 17.24**) and inject 4 to 5 mL anesthetic until hydrodissection is observed (**see FIGURE 17.2**).

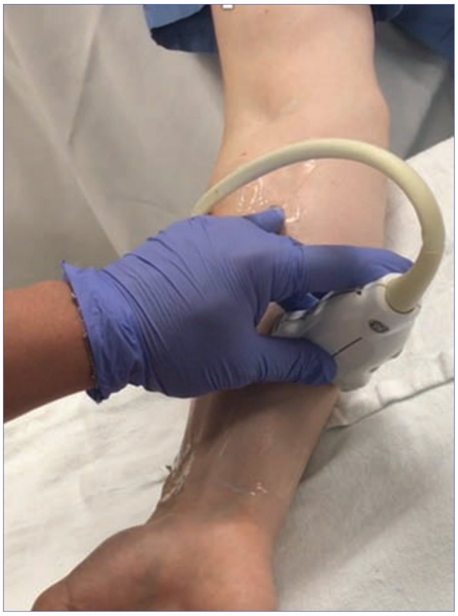


FIGURE 17.23 Mid-forearm location for nerve visualization.

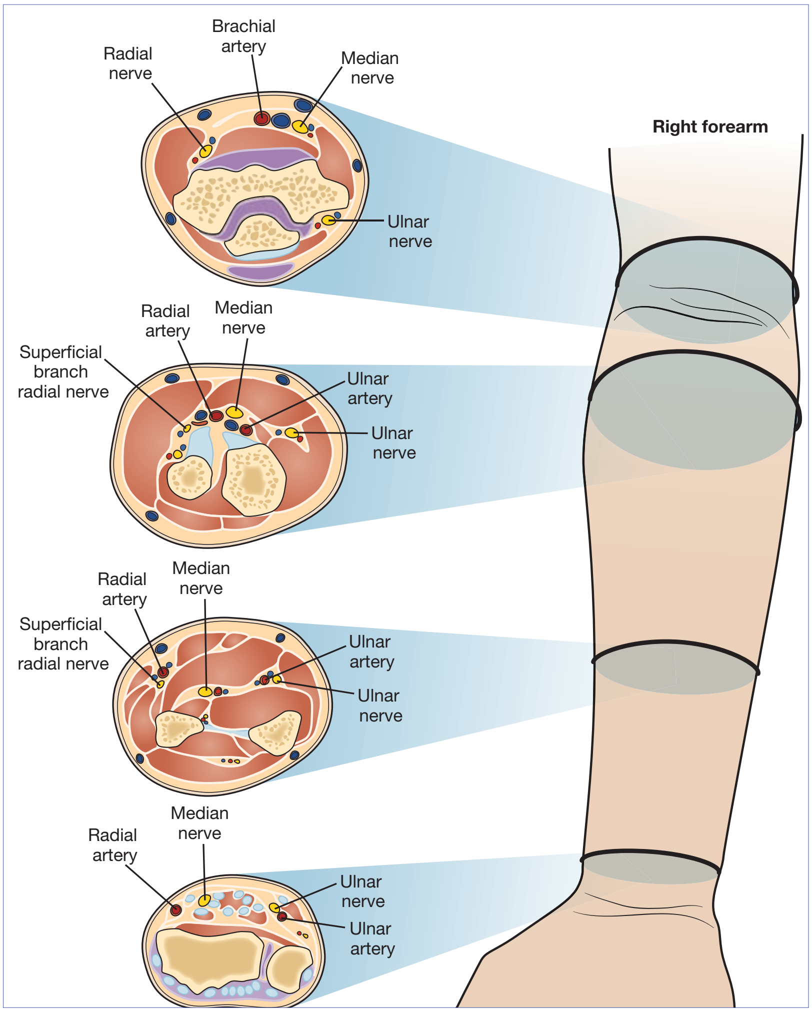

Brachial artery
Radial nerve
Median nerve
Right forearm
Ulnar nerve
Radial artery
Median nerve
Superficial branch radial nerve
Ulnar artery
Ulnar nerve
Radial artery
Median nerve
Superficial branch radial nerve
Ulnar artery
Ulnar nerve
Median nerve
Radial artery
Ulnar nerve
Ulnar artery

FIGURE 17.24 Position of the needle adjacent to median nerve just prior to injection.

PEARL

- For forearm blocks, position yourself facing the ultrasound machine with your dominant hand holding the needle. For some blocks, you will face the patient and in others you will face the other way.

ULNAR NERVE

PATIENT PRESENTATION

A 19-year-old male presents with swelling and pain to the area of the fifth metacarpal after punching a cement wall. Imaging confirms a displaced fracture of the fifth metacarpal.

TREATMENT

The fracture needs to be reduced and splinted. A UGNB of the ulnar nerve can be performed prior to reduction.

SPECIAL CONSIDERATIONS

- The ulnar nerve travels closely with the artery from the mid-forearm to the wrist. A more proximal site, where the path of the nerve separates from the artery, should be chosen.

PROCEDURE PREPARATION

- Needle, 22 to 25 gauge
- 4 to 5 mL of anesthetic

PROCEDURE

- Place the patient's forearm on a procedure table or tray in supine position.
- Place the probe on the volar aspect of the arm in the transverse orientation just proximal to the wrist.
- Locate the ulnar nerve, which has a triangular or oval shape, next to the ulnar artery in the wrist (**FIGURE 17.25**).
- Slide the probe proximally until the ulnar artery separates from the nerve to take a deeper and more lateral course (**FIGURE 17.26**).
- Insert the needle just adjacent to the nerve and inject 4 to 5 mL of anesthetic until hydrodissection is observed.

POSTPROCEDURE CONSIDERATIONS

None.

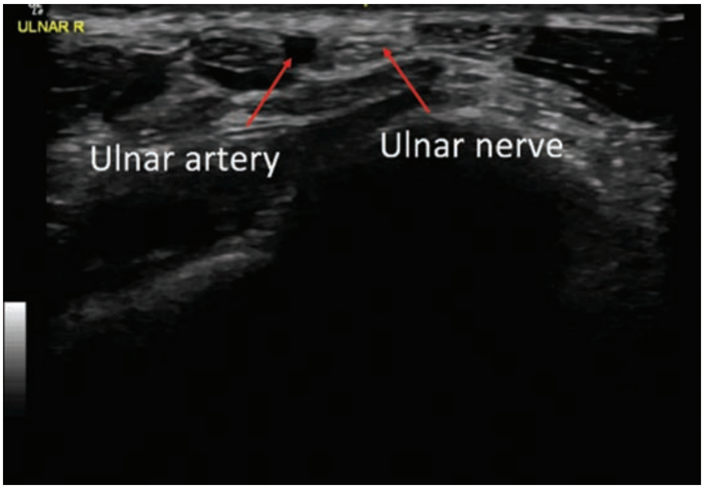


FIGURE 17.25 The ulnar nerve is just medial to the ulnar artery in the distal forearm in this right forearm view.

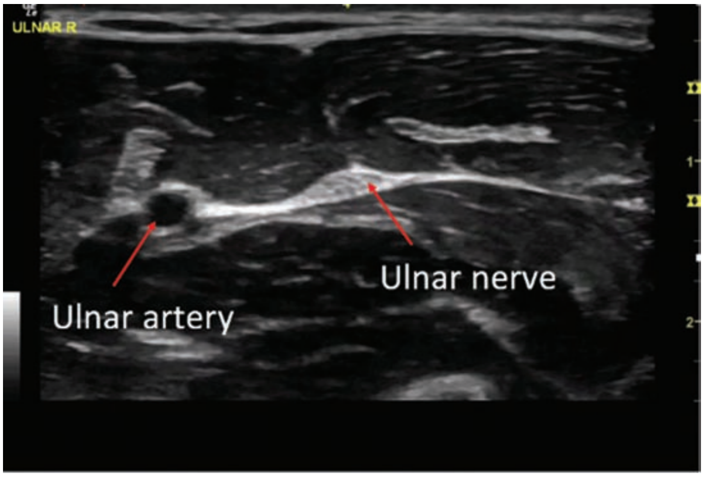


FIGURE 17.26 In the right mid-forearm, the ulnar nerve dives deep laterally, separating from the nerve. This is an ideal area to use to target the ulnar nerve.

PEARL

- In order to visualize the in-plane needle trajectory without rotating the patient's arm to an uncomfortable degree, the needle can enter the skin in the lateral aspect of the arm rather than just adjacent to the probe on the volar surface.

RADIAL NERVE

A 30-year-old female with history of intravenous drug use (IVDA) presents with a large abscess to the dorsal surface of the hand, distal to the index finger, where she injected heroin last week.

TREATMENT

The abscess needs to be incised and drained. A UGNB of the radial nerve will provide analgesia for the procedure.

SPECIAL CONSIDERATIONS

Like the ulnar nerve, the radial nerve travels close to the radial artery from the mid-forearm to the wrist. A more proximal site, where the path of the nerve separates from the artery, should be chosen.

PROCEDURE

1. Place the patient's forearm on a procedure table or tray in supine position.
2. Place the probe on the volar aspect of the arm in the transverse orientation just proximal to the wrist.
3. Locate the radial nerve, which has a triangular shape, next to the radial artery in the wrist (**FIGURE 17.27**).
4. Slide the probe proximally until the radial artery separates from the nerve (**FIGURE 17.28**).
5. The radial nerve can be the most challenging forearm nerve to visualize as it often has a "flattened" appearance.
6. If the radial nerve is not well visualized distal to the elbow or anesthesia to the distal radial head is desired, the radial nerve can be targeted in the supracondylar region about 3 to 4 cm above the elbow crease (**FIGURES 17.29** and **17.30**).
7. Insert the needle just adjacent to the nerve and inject 4 to 5 mL of anesthetic until hydrodissection is observed.

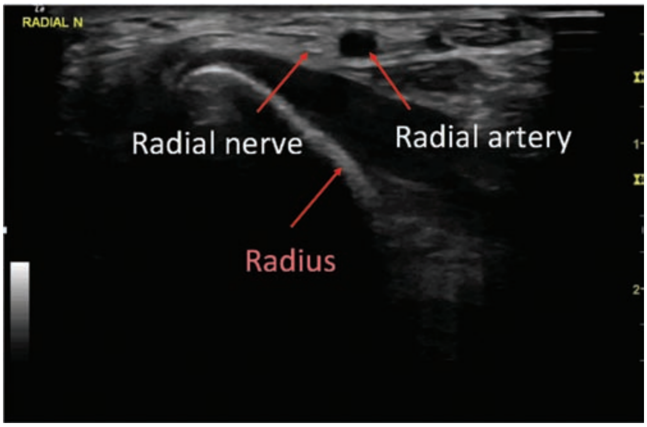


FIGURE 17.27 The radial artery and nerve travel together in the right wrist area.

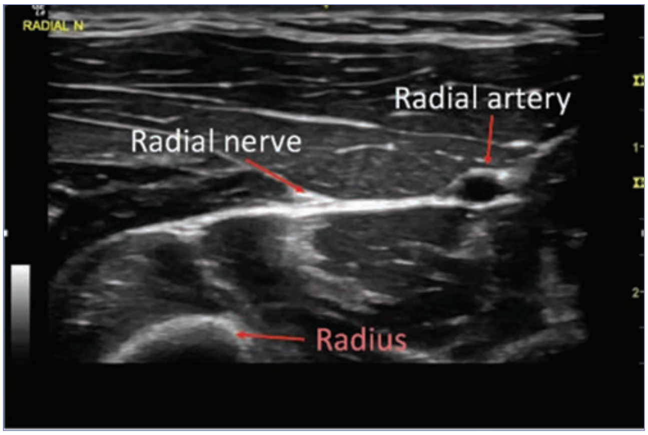

RADIAL N
Radial artery
Radial nerve
Radius

FIGURE 17.28 In the proximal forearm, the radial nerve separates and travels medial to the artery, making it an ideal location for blockade.

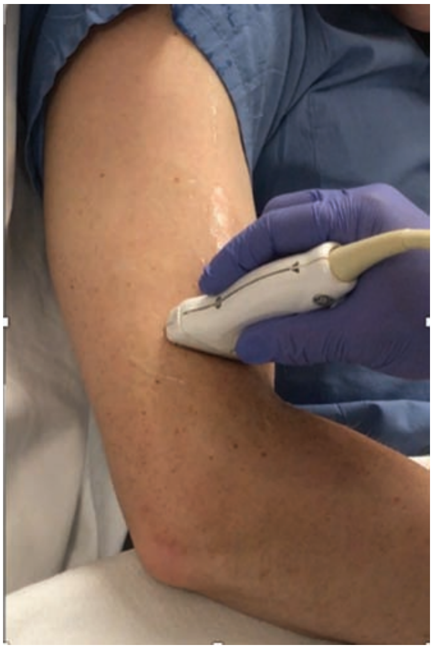


FIGURE 17.29 Probe position for supracondylar radial UGNB.

UGNB, ultrasound-guided nerve block.

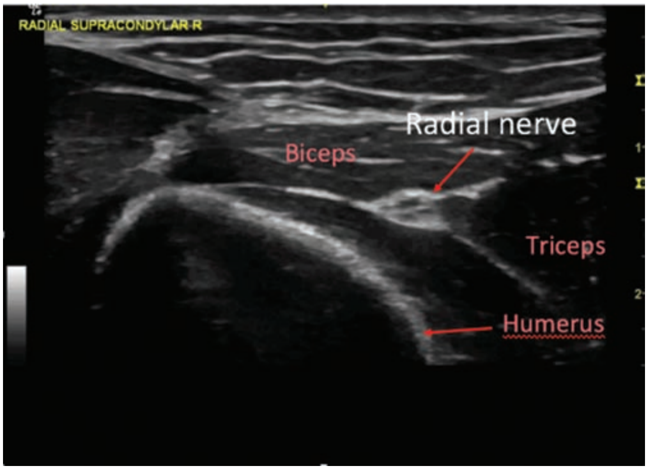

RADIAL SUPRACONDYLAR R
Radial nerve
Biceps
Triceps
Humerus

FIGURE 17.30 The radial nerve is well visualized in the supracondylar region.

POSTPROCEDURE CONSIDERATIONS

- None.

PEARLS

- The radial nerve in the forearm is a sensory branch, whereas the supracondylar radial nerve contains both sensory and motor fibers.
- To direct anesthesia to the distal radius, the supracondylar approach must be utilized.

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CHAPTER
18

Procedures for Performing Digital Anesthesia

Jessica Fujimoto and Kraftin E. Schreyer

BACKGROUND

By far, a digital nerve block is the most commonly used regional nerve block in the outpatient setting. It provides fast, effective, and simple anesthesia. Because the structure of the distal finger has fibrous septations, local infiltrative anesthesia is not only impractical but also nearly impossible.

As in most procedures, the key to a successful outcome is a fundamental understanding of the anatomy. In the upper extremities, a common digital nerve runs along the side of the metacarpals and, at the level of the metacarpal heads, bifurcates into volar and dorsal tributaries (**FIGURE 18.1**).

In the lower extremities, separate dorsal and plantar nerves bifurcate at the level of the metatarsal heads to innervate medial and lateral aspects of adjacent digits (**FIGURE 18.2**).

The end result is that both upper and lower extremity digits have nerves that lay alongside the phalanx at the 2, 10, 4, and 8 o'clock positions (**FIGURE 18.3**). The thumb and hallux (great toe) have accessory nerves running over the dorsal lateral surface, much more so than the other digits; because of this, the provider should make a circumferential subcutaneous ring pattern with the local anesthetic.

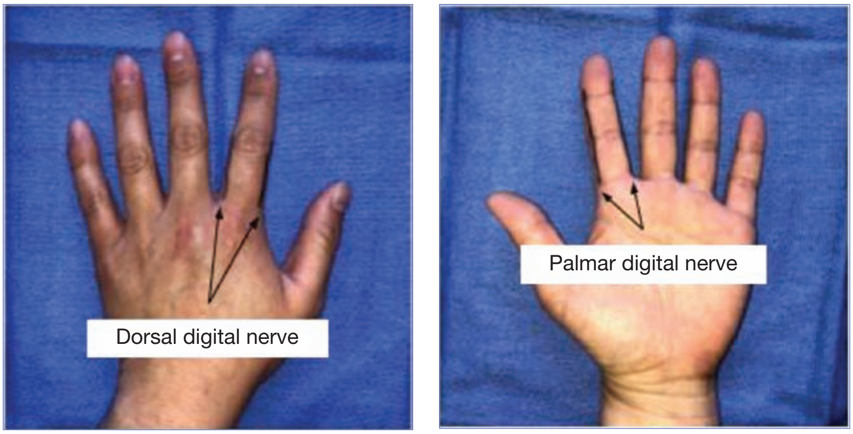

FIGURE 18.1 Upper extremity digit innervation.

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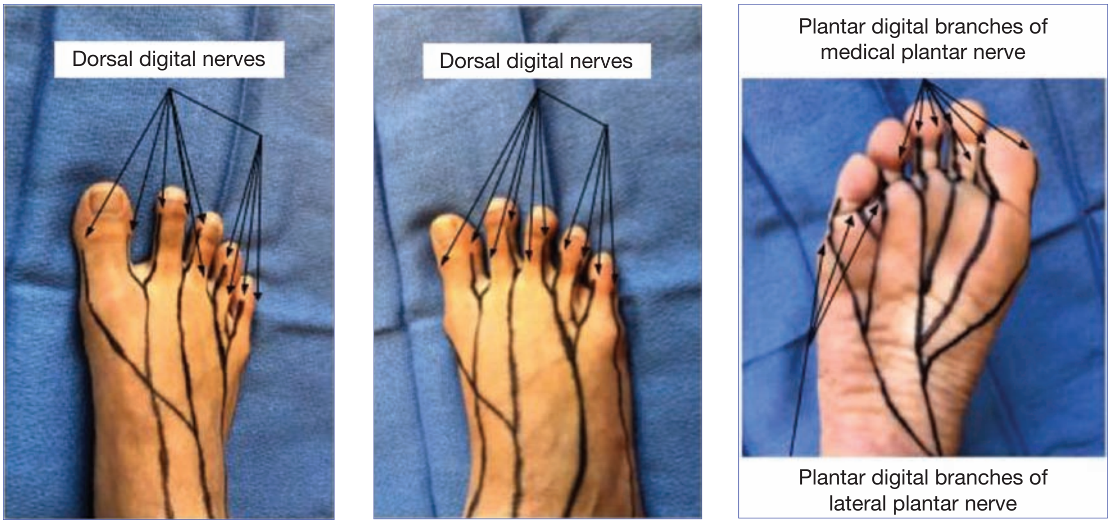

Dorsal digital nerves
Dorsal digital nerves
Plantar digital branches of medical plantar nerve
Plantar digital branches of lateral plantar nerve

FIGURE 18.2 Lower extremity digit innervation.

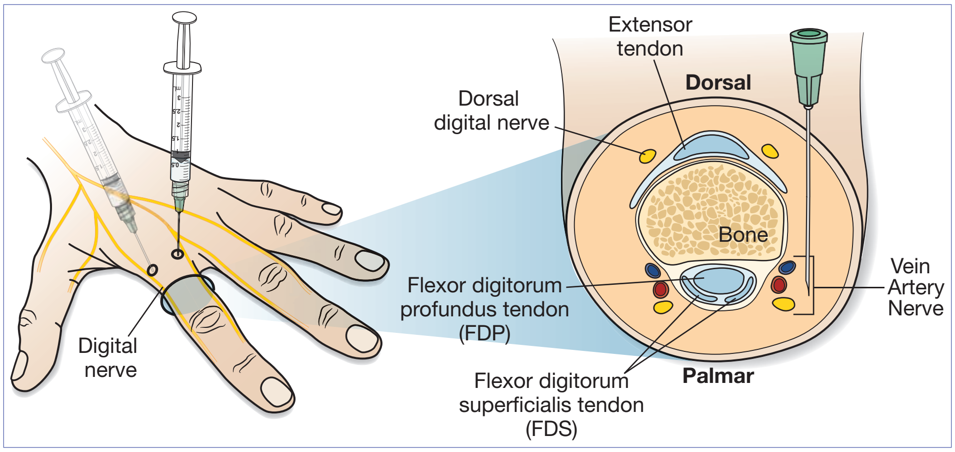

Extensor tendon
Dorsal
Dorsal digital nerve
Bone
Vein
Artery
Nerve
Flexor digitorum profundus tendon (FDP)
Digital nerve
Flexor digitorum superficialis tendon (FDS)
Palmar

FIGURE 18.3 Cross-section of the finger. Note needle position with regard to the digital nerves.

PATIENT PRESENTATION

Digital pathology of the finger/toe, including the following:

- Repair of finger lacerations and amputations
- Paronychia incision and drainage
- Nail bed injuries and nail removal
- Fracture reduction
- Dislocation reduction
- Ring removal
- Tendon injuries
- Pain relief

TREATMENT

Local anesthetic injection should occur at least 10 minutes before the procedure to allow complete anesthesia. Although it is commonly stated that epinephrine should not be used, there is no evidence supporting this. In fact, according to current evidence, the use of epinephrine with lidocaine in standard commercial concentrations for digital blocks is not harmful and is likely advantageous, as epinephrine with lidocaine may double the duration of action, decreasing the use of tourniquets and repeated sticks.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Compartment syndrome of the finger
- Allergy to anesthetic
- Infection at injection site
- Compromised digital circulation

Relative Contraindications to Use of Epinephrine

- Severe peripheral vascular disease
- Raynaud syndrome
- Thromboangiitis obliterans

SPECIAL CONSIDERATIONS

Techniques to Reduce Pain

- Use a small-gauge needle (25, 27, or 30-gauge).
  - Arendt-Nielsen et al. (2006) have shown that the outer needle diameter was positively and significantly correlated to the frequency of the insertion pain:
    - 63%—23 gauge
    - 53%—27 gauge
    - 31%—32 gauge
- Slowly infiltrate.
- Insert needle perpendicular to the skin. Martires et al. (2011) have shown that there was significantly less pain with injections done at 90 degrees versus those done at 45 degrees.
- Keep some visible anesthetic ahead of the needle's tip. Almost always, pain after the first poke is caused by the needle tip hitting nerves that have not yet been anesthetized. When moving laterally beneath the skin, it is important to keep 5 mLs of palpable or visible local anesthetic ahead of the tip; it anesthetizes the subdermal nerve endings.
- Warm the fluid. Sultan (2007) has reviewed 11 papers studying the warming effect of a local anesthetic in regard to decreasing pain and has concluded that warmed local anesthetic solution is significantly less painful than solution at room temperature.
- Use a buffered solution. With an acidic pH of 4.7, lidocaine can cause an unpleasant burning sensation.
  - A Cochrane meta-analysis (Cepeda et al., 2010) of several randomized controlled trials (RCTs) determined that the addition of sodium bicarbonate (10:1 lidocaine: sodium bicarbonate [8.4% $NaHCO_3$]) can considerably minimize pain.

Choosing a Technique

Dorsal and palmar approach techniques are considered equally efficacious in anesthetizing the upper extremity. Some considerations are listed in **TABLE 18.1**.

TABLE 18.1 Comparison of Upper Extremity Digital Block Approaches

Type of Block	Advantage	Disadvantage
Double dorsal	■ Dorsal approach less painful	■ Two entry points ■ Some delay of anesthesia onset may occur ■ Possible tourniquet effect
Ring	■ Dorsal approach less painful ■ Improved anesthesia of thumb and great toe	■ Two entry points ■ Some delay of anesthesia onset may occur ■ Possible tourniquet effect
Transmetacarpal	■ Dorsal approach less painful	■ Two entry points ■ Anesthetizes adjacent finger ■ Higher risk of neurovascular injury
Single volar subcutaneous	■ Single entry point	■ Palmar approach more painful ■ Poor anesthesia of proximal dorsal digit ■ Usually requires 3–4 mL of anesthesia
Transthecal	■ Single entry point	■ Palmar approach more painful ■ Poor anesthesia of proximal dorsal digit

PROCEDURE PREPARATION

Materials

- Skin antiseptic solution
- Bupivacaine or lidocaine
- 25- or 27-gauge needle
- 3- or 5-mL syringe

Preparation

- Perform a thorough neurovascular exam of the digit.
- Position patient supine with the finger or toe well exposed and comfortably resting on a clean surface.
    - Clean injection sites with alcohol swab or other prep.
    - Use aseptic technique.

PROCEDURE

Upper Extremity Blocks

DOUBLE DORSAL

- The volar surface of the hand is placed on the table.
- The needle is inserted at a 90-degree angle in the dorsal hand at the level of the web space. A 0.5- to 1-mL deposit is injected in the dorsal surface of the finger (**FIGURE 18.4**; **VIDEO 18.1**).
- The needle is advanced until the volar skin is tenting. The needle is withdrawn 1 mm, then 0.5 to 1 mL of anesthetic is injected.
- The needle is reinserted in the dorsal surface of the opposite side as described previously.
    - It is imperative to test the digital block before performing the procedure via pinprick test (**VIDEO 18.2**).

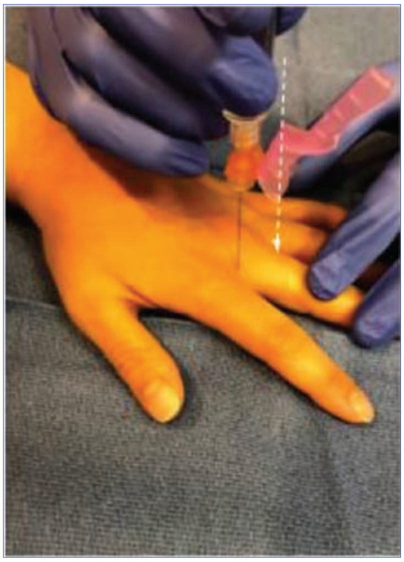
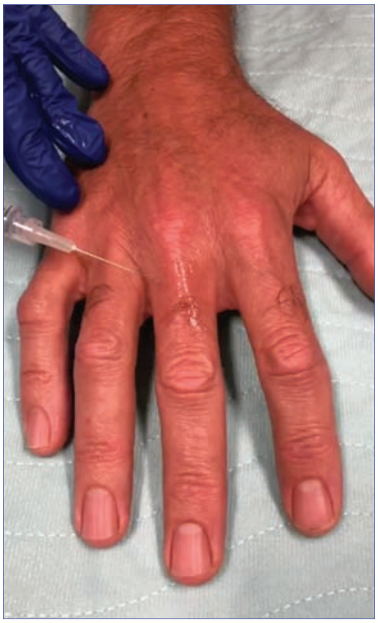


FIGURE 18.4 Double dorsal injection site for second digit.



VIDEO 18.1 Double dorsal injection of the third digit.

VIDEO 18.2 Testing of palmer and dorsal digital nerves after digital block anesthesia.

RING BLOCK

- The volar surface of the hand is placed on the table.
- The needle is inserted at the ulnar or radial aspect of the dorsal hand at the level of the web space. A 0.5- to 1-mL deposit is injected as the needle is advanced across the dorsal surface of the finger.
- The needle is withdrawn to the entrance site without removing the needle from the skin.
- The needle is then redirected at a 90-degree angle toward the palmar aspect. The needle is advanced until the volar skin is tenting. The needle is withdrawn 1 mm, then 0.5 to 1 mL of anesthetic is injected.
- The needle is reinserted in the other side of the finger through the anesthetized dorsal surface as described previously (**FIGURE 18.5**; **VIDEO 18.3**).

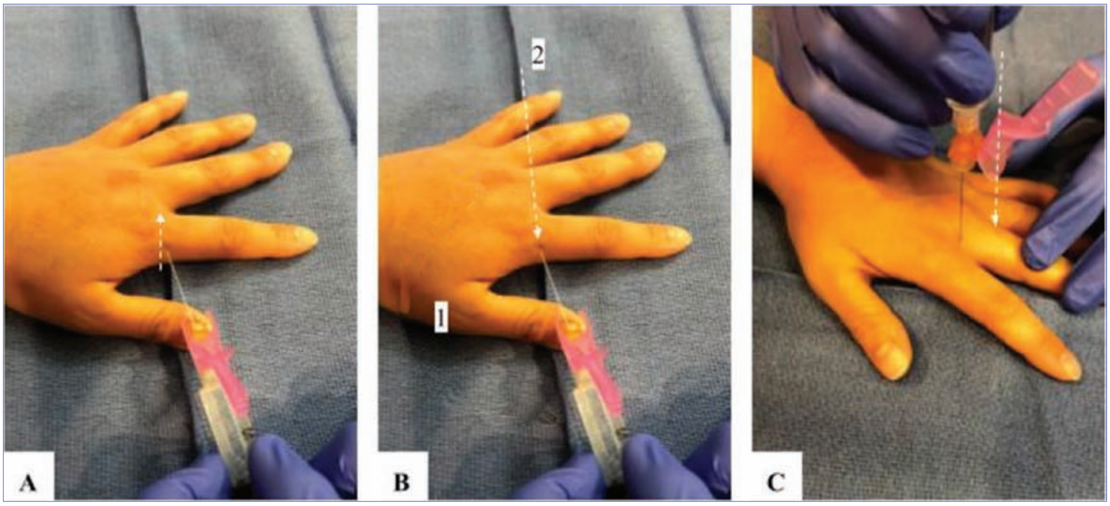
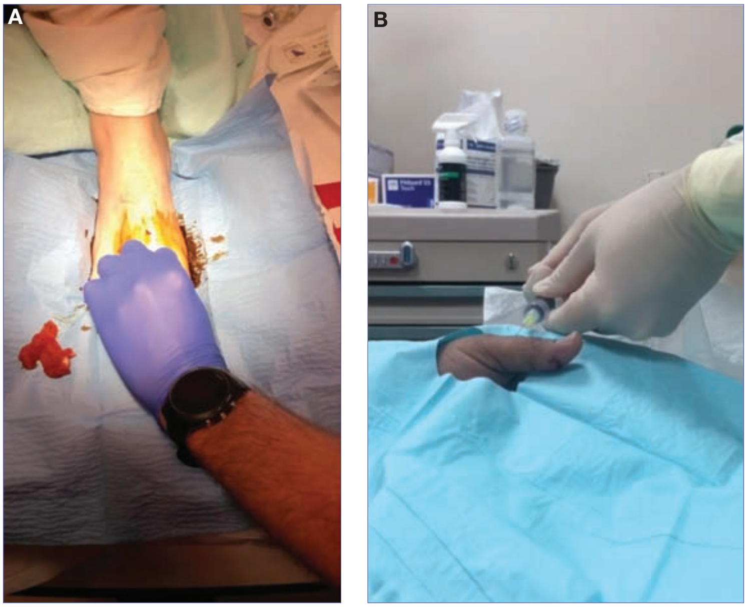


FIGURE 18.5 Ring block technique for second digit. (A) Insert needle as shown and inject as needle is advanced across dorsal surface of finger. Withdraw needle to the entrance site without removing the needle from the skin. (B1) Reposition needle. (B2) Advance needle toward the palmar aspect. Inject at palmar aspect and as needle is withdrawn again toward dorsal aspect. (C) Reinsert needle in the other side of the finger.

VIDEO 18.3 Digital anesthesia of (A) toe and (B) thumb.



TRANSMETACARPAL BLOCK

Metacarpal blocks may still have a role when anesthesia is required in more than one finger, when proximal anesthesia is needed, or when the circulation to the finger is suspect.

- The volar surface of the hand is placed down on the table.
- The needle is inserted at a 90-degree angle in the dorsal hand at the level of the metacarpal phalangeal joint. A 0.5- to 1-mL deposit is injected in the dorsal surface of the finger.
- The needle is advanced until the volar skin is tenting. The needle is withdrawn 1 mm, then 0.5 to 1 mL of anesthetic is injected.
- Upon slow withdrawal of the needle, an additional 0.5 mL of local anesthetic is deposited.
- The needle is reinserted in the opposite side dorsal surface as described previously (**FIGURE 18.6**).

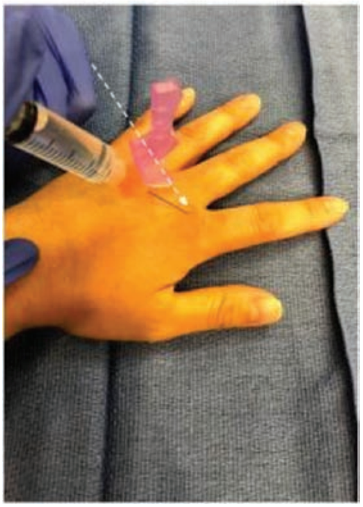


FIGURE 18.6 Transmetacarpal block injection site for second digit.

SINGLE VOLAR SUBCUTANEOUS

- The dorsal surface of the hand is placed on the table.
- The needle is inserted into the skin at a 90-degree angle at the level of the proximal palmar flexion crease.
- Inject anesthesia as needle is advanced. Advance until bony resistance is met.
- Inject 3 to 4 mL of anesthetic. Withdraw 3 to 4 mm and inject anesthetic to left and right of midline to anesthetize both digital nerves **(FIGURE 18.7)**.

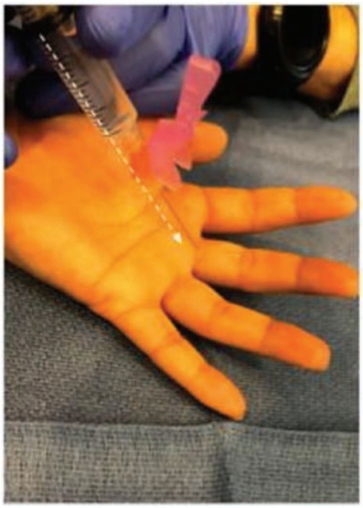


FIGURE 18.7 Single volar subcutaneous and transthecal block injection site for third digit.

TRANSTHECAL BLOCK

- The dorsal surface of the hand is placed on the table.
- The needle is inserted into the skin at a 90-degree angle at the level of the proximal palmar flexion crease just proximal to the metacarpophalangeal (MCP) joint; ultrasound guidance is recommended (**FIGURE 18.8**).
- Advance needle until resistance is met. Then advance needle a few millimeters further, until needle is deep in the flexor tendon sheath.
- Inject 2 to 3 mL of anesthetic.
    - If the sheath has been entered correctly, the LA should flow freely when gentle pressure is applied to the plunger; if this does not occur, withdraw 1 to 2 mm and try again (**VIDEO 18.4**).

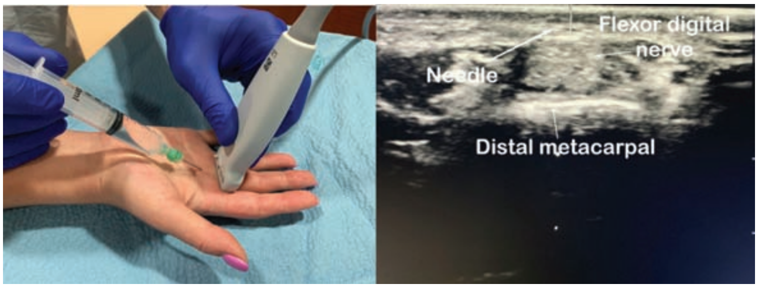
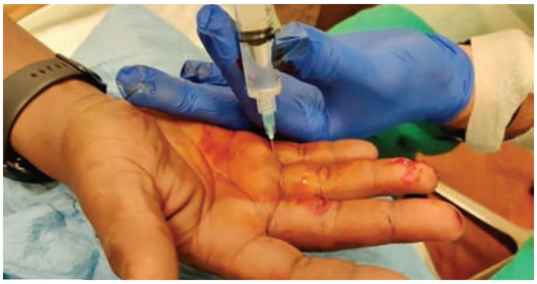


FIGURE 18.8 Transthecal digital nerve block using POCUS guidance.



VIDEO 18.4 Transthecal digital block.

Lower Extremity Blocks

WEBSPACE BLOCK

- The plantar surface of the foot is placed down on the bed.
- The needle is inserted at a 90-degree angle in the dorsal foot at the level of the web space. A 0.5- to 1-mL deposit is injected into the dorsal surface of the toe.
- The needle is advanced until the plantar skin is tenting. The needle is withdrawn 1 mm, then 0.5 to 1 mL anesthetic is injected.
- Upon slow withdrawal of the needle, an additional 0.5 mL of local anesthetic is deposited.
- The needle is reinserted in the opposite side dorsal surface as described previously (**FIGURE 18.9**).

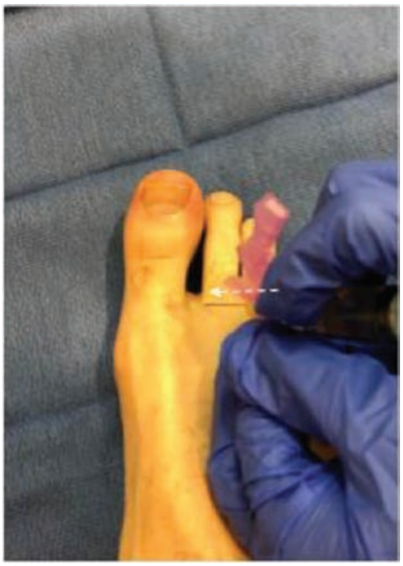


FIGURE 18.9 Webspace block injection site for second digit.

METATARSAL BLOCK

- The plantar surface of the foot is placed down on the bed.
- The needle is inserted at a 90-degree angle in the dorsal foot between metatarsals, injecting 1 mL of anesthetic into the dorsal skin.
- The needle is advanced toward the plantar aspect, tenting the skin. An additional 2 mL is injected while withdrawing needle to the level of the skin.
- The needle is again advanced at a different angle toward the plantar skin. The process is repeated to inject a total of 5 mL of anesthetic into one metatarsal space.
- The technique is repeated for the adjacent webspace to fully anesthetize the desired digit (**FIGURE 18.10**).

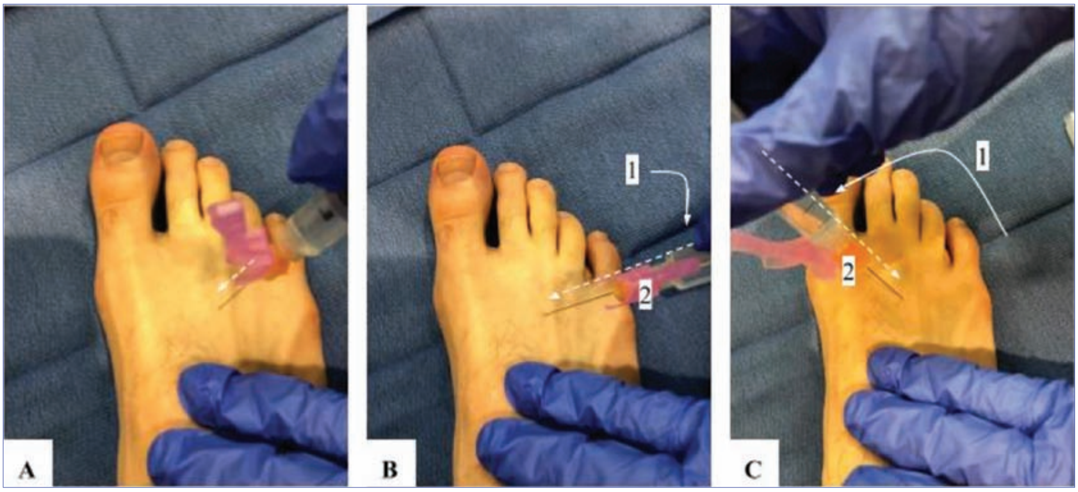


FIGURE 18.10 Metatarsal block technique. (A) Insert needle as shown at 90-degree angle between metatarsals. Inject anesthetic in dorsal skin. Advance needle toward plantar aspect of foot. Inject anesthetic while withdrawing needle to the entrance site without removing the needle from the skin. (B1) Reposition needle. (B2) Advance at a different angle toward the plantar skin. Repeat injection of anesthetic as described in (A). (C) Repeat technique as described in (B1) and (B2).

COMPLICATIONS

The complication rate is low, but possibilities include:

- Tendon injuries
- Nerve trauma
- Distal ischemia—Consider topical nitroglycerin for persistent ischemia or local infiltration of phentolamine if using epinephrine
- Local anesthetic toxicity
- Intravascular injection
- Hematoma formation or bleeding
- Infection

PEARLS

- Perform a thorough neurovascular exam prior to injecting anesthesia.
- Allow adequate time for onset of this peripheral nerve block—at least 10 minutes.
- Bupivacaine lasts longer than lidocaine.
- Epinephrine-containing anesthetic solution is safe to use in healthy patients, but can be considered in patients with poor peripheral circulation.
- The finger tips are not amenable to the infiltrate of local anesthesia secondary to fibrous septae.

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CHAPTER

19

Procedures for Performing Bier Anesthesia

Ernest Leber and Keith Lafferty

BACKGROUND

Intravenous regional anesthesia (IVRA) is commonly referred to as the *Bier block (BB) or Bier anesthesia (BA)* technique. ***It is one of the oldest anesthetic techniques still in use today, with more than 100 years of use; this attests to its safety and utility in a wide variety of procedures***. This technique can provide complete anesthesia, muscle relaxation, and a bloodless field in the distal upper and lower extremities to allow repair or reduction of lacerations, fractures, dislocations, burn care, drainage of abscesses, and care of other soft tissue injuries. It was first described in 1908 by August Gustav Bier and since has been shown to be safe, effective, and easy to perform not only in the operating room but also the ED and outpatient clinics. The advantages of the BB include its lack of need for sedation, minimal allocation of resources from a busy ED or clinic, and the ability for a patient to be treated and discharged in a timely manner.

The technique involves the injection of local anesthetic (LA) intravenously into an extremity while a proximally placed pneumatic tourniquet (PT) device is inflated to such a high pressure that arterial blood flow distal to the tourniquet ceases, as does venous return. The LA that is injected is "trapped" in the area below the tourniquet and consequently remains in the portion of the extremity below or distal to the blood pressure (BP) cuff, subsequently causing complete anesthesia to this region.

Mechanism of action does not have full consensus; however, it is generally agreed upon that the LA permeates the venous walls and capillaries and remains in the portion of the extremity distal to the PT, where action of the drug can take effect in the extravascular space, hence bathing peripheral nerve trunks, inner fascicles, and eventually individual axons. Sodium channel blockade of these sensory nerves as well as motor nerves (inhibits propagation so there is no depolarization and subsequent activation of signaling at the neuromuscular junction) ensues, with the sequela of complete anesthesia and muscle paralysis. Ischemia and acidosis from the tourniquet contribute to the anesthesia, although the LA is the main factor. Besides simple diffusion across venous and capillary walls into the extravascular space and consequent bathing of neurons, histological studies have shown that direct vascular channels via the vasa nervorum (blood supply to the nerve itself) allow the LA directly into the nerve's trunks/fascicles via the capillary side of the vasa nervorum, again achieving regional anesthesia in the entire extremity below the inflated PT. It is noteworthy to proclaim that the anesthesia obtained occurs in a few minutes and in a centripetal manner, which moves from the fingers proximally. Because nerve trunks are constructed with fibers from the periphery nearest the center, this gives further support to the preceding text, further suggesting that LA's solution reaching the nerves through the veins would be expected to affect the nerve fibers from the fingers first (**FIGURE 19.1**).

Multiple studies have evaluated the safety of the technique. ***Compared to patients with axillary block or lumbar epidural anesthesia for similar procedures, IVRA actually had significantly lower plasma lidocaine concentrations***. There have been thousands of patient cases analyzed in the literature showing extremely low complication rates. ***There have been no reported deaths when lidocaine is used as the LA and the rate of treatment failure is also extremely low***.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

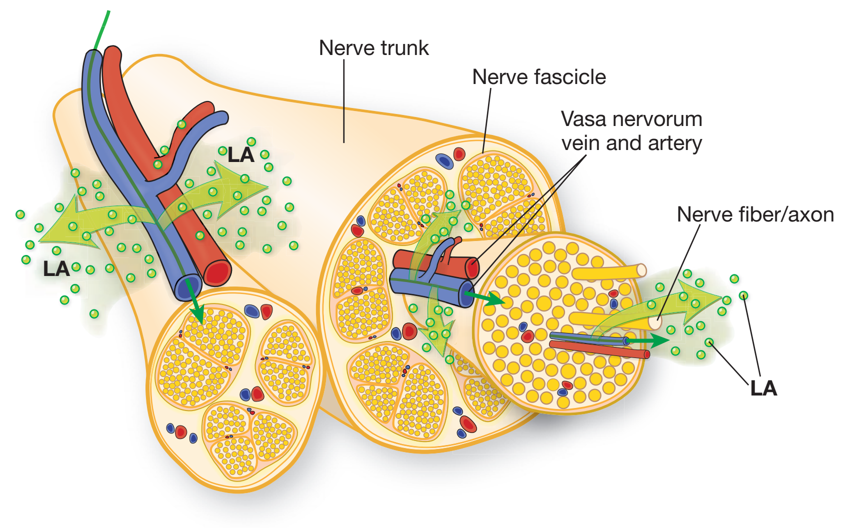


FIGURE 19.1 Peripheral nerve trunk. Within the nerve trunk are many well-organized fascicles, each carrying individual neurons. Blood is supplied to the nerves themselves via the vasa nervorum, which are tributaries from larger vessels. In a Bier block, it is postulated that the LA reaches the nerve via this vascular network as well as diffusing directly out of the venous walls into the extravascular space engulfing the nerves, directly bypassing the vasa nervorum.

LA, local anesthetic.

PATIENT PRESENTATION

IVRA is most effective for patients presenting with injuries below the knee or elbow. It is an effective technique with the following benefits:

- Bloodless field
- Complete anesthesia
- Muscle relaxation
- Rapid onset/rapid recovery
- Controlled duration
- Safe
- Effective (96%–100%)

Clinical procedures that lend themselves to this technique include the following:

- Reduction of dislocations
- Reduction of fractures
- Repair of major soft-tissue lacerations
- Repair of tendon lacerations
- Removal of foreign bodies
- Debridement of extremity burns
- Drainage of extensive infections (abscess incision and drainage [I&D])
- Fasciotomy (compartment syndrome)

TREATMENT

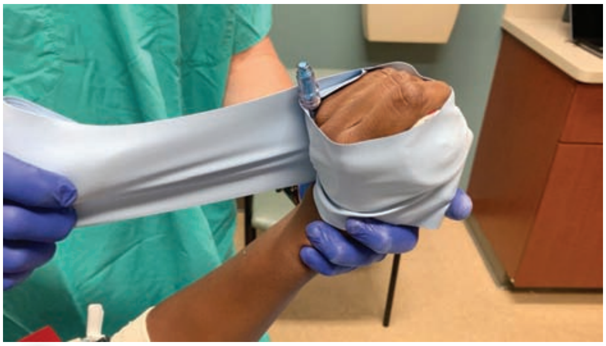
As noted previously, because the position of the PT overlies the proximal extremity, this IVRA procedure is best used for injuries at or below the elbow and knee. The area should be exsanguinated (venous blood) before the procedure begins in order to maintain a bloodless field. The PT has classically been inflated in the upper arm or leg, allowing access to the distal extremities (**VIDEOS 19.1** and **19.2**). There is more recent literature that advocates for tourniquet placement below the elbow and at the level of the mid-calf below the peroneal nerve and knee when applicable, depending upon the area of repair. With a distally placed PT, less LA may be used and tourniquet pain is also decreased.

A standard, single BP cuff is not adequate to perform this procedure as cuffs are prone to leakage and bladder rupture, which may result in loss of compression and systemic leakage of LA into the systemic circulation. Although a commercially available pneumatic cuff system is recommended, the procedure has been safely performed using standard BP cuffs in EDs for many years. If using standard BP cuffs, one must ensure that there is no air leakage when the cuffs are fully inflated. Taping around the cuff to prevent the cuff from unfolding and clamping the cuff inflation hose with a hemostat after insufflation can help prevent the loss of cuff pressure. Also, prophylactically and simultaneously using a second cuff ensures a "backup" measure against a primary cuff failure.

The ideal PT to use is a dual-cuff automatic tourniquet system (DCATS) as it continuously checks the pressure and if a decrease in pressure is detected, air immediately enters automatically to further maintain the desired occlusion. As stated, if a DCATS is not available, one may *cautiously* use two standard manual BP cuffs (proximal and distal cuffs) in order to safeguard against a leak and subsequent release of a large bolus of LA into the systemic circulation. In either case, the proximal cuff is inflated first and only after onset of anesthesia distal to this cuff is reached, then the distal cuff is inflated over the anesthetized area. When using the DCATS, the proximal cuff is deflated in an effort to decrease the pain induced by the cuff pressure over the nonanesthetized area. *However, if a DCATS is not available and one is using two standard BP cuffs, to further safeguard against a loss of cuff pressure, we recommend keeping the proximal and distal manual BP cuffs inflated throughout the procedure and using clamped hemostats over the tubing distal to the inflation bulb/air-release valve*.

Once an appropriate patient is identified, preparation can begin. It is always prudent to have general resuscitative equipment nearby and ready in case of an unforeseen complication. One must be prepared to deal with local anesthetic systemic toxicity (LAST) and should have a prepared intralipid emulsion and a benzodiazepine available. The LA of choice is preservative-free lidocaine *without* epinephrine. This is the same lidocaine that is found on a code cart. It is given in a concentration of 0.5% (1% lidocaine diluted with an equal part of normal saline solution (NSS) to yield 0.5% lidocaine (5 mg/mL). ***It has been shown that at similar doses (mg/kg), the more dilute the concentration, the less LA enters the systemic circulation***. In a standard BB, lidocaine is dosed at 3 mg/kg, but a mini dose of 1.5 mg/kg has also been described with upper extremity blocks when the tourniquet is placed below the elbow. *Bupivacaine is contraindicated and should never be used as it is more likely to have toxicity owing to its longer half-life*. Anesthesia occurs quickly and will begin in 5 to 10 minutes starting distally in the hand/feet and progressing proximally to other parts of the arm up to the tourniquet and should be complete in 20 minutes. If using the mini dose an additional 1 to 1.5 mg/kg may be necessary to achieve full anesthesia. The procedure may then be performed. ***The PT should be left in place for at least 20 to 30 minutes to allow complete diffusion out of the vasculature and tissue binding of the LA***. After 30 minutes, the PT may be deflated in a cyclic manner releasing pressure for 5 seconds then reinflating for 1 to 2 minutes for two to three cycles. The PT should not be left on for more than 60 to 90 minutes to avoid compression and ischemic injury to the extremity.

VIDEO 19.1 Application of pneumatic tourniquet cuff and connectors. Not shown is the recommended use of a stockinette. Please note the step of using the Esmark elastic bandage wrap before inflation of the PT is shown in **VIDEO 19.2**.



VIDEO 19.2 It is recommended to exsanguinate the area distal to the cuff via use of an Esmark elastic bandage, wrapping from the distal fingers in a proximal direction to the pneumatic cuff in an effort to rid the venous blood from the extremity. At this point, the pneumatic cuff can be inflated in order to cease the arterial blood flow to the extremity. Last, we recommend use of a dual-cuff automated tourniquet, although the video shows a single-cuff automated tourniquet.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Absolute Contraindications

- No intravenous (IV) access
- Allergy to lidocaine (extremely rare)
- Unreliable tourniquet

Relative Contraindications

- Uncooperative patient
    - Intoxicated
    - Uncooperative
    - Obtunded
- Raynaud's disease
- Buerger's disease
- Severe obesity
- Severe arteriosclerosis
- An ischemic or crushed extremity
- Infection of the cuff site
- Peripheral vascular disease
- Homozygous sickle cell (SS) disease
- Venous disruption from injury
- Arteriovenous shunts
- Significant cardiac disease
- Elderly

SPECIAL CONSIDERATIONS

As mentioned previously, use of a forearm tourniquet technique with a mini dose of LA (1.5 mg/kg) has also been shown to be safe and effective. Less ischemic pain and less total LA use means decreased potential adverse reactions. ***In a systematic review, forearm IVRA was equally effective in providing a surgical block as compared to conventional upper arm IVRA, even with a reduced dose of LA***. A BB with LA dosed at 1.5 mg/kg was shown to have a 93% success rate.

PROCEDURE PREPARATION

For the equipment needed to perform IVRA, see **TABLE 19.1** and **FIGURE 19.2**

TABLE 19.1 **Equipment Needed to Perform IVRA and Their Uses**

Equipment	Use
General resuscitation equipment	Prepare for potential LAST
IV catheter placed in the injured extremity	To give LA
IV catheter placed in the uninjured extremity	In case of resuscitation
60 mL syringe	To draw up LA to be given
Esmark elastic bandage	To exsanguinate the extremity of venous blood
Lidocaine—diluted to 0.5%; 3 mg/kg full dose or 1.5 mg/kg mini dose	For anesthesia of the affected extremity
(DCATS; **FIGURE 19.3**)	To obtain arterial occlusion of the extremity with a two tourniquet system

DCATS, dual-cuff automatic tourniquet system; IV, intravenous; IVRA, intravenous regional anesthesia; LA, local anesthetic; LAST, local anesthetic systemic toxicity.

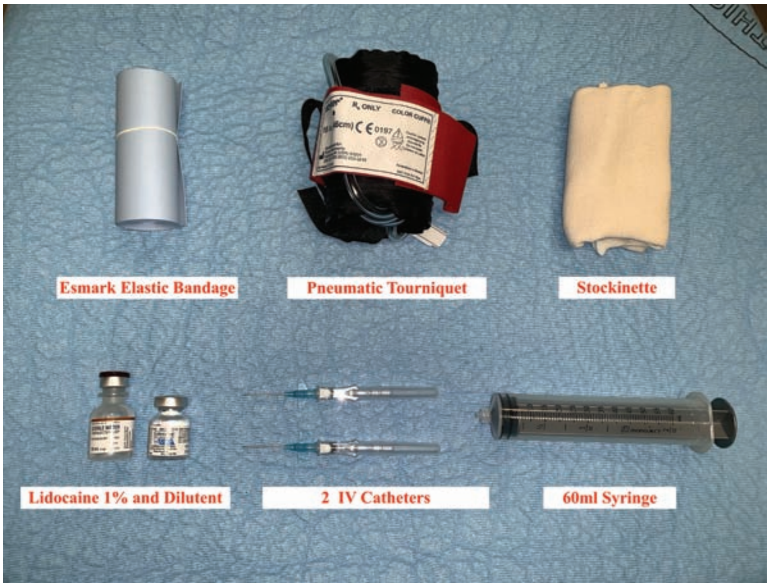


FIGURE 19.2 IVRA (Bier block) equipment.

IV, intravenous; IVRA, intravenous regional anesthesia.

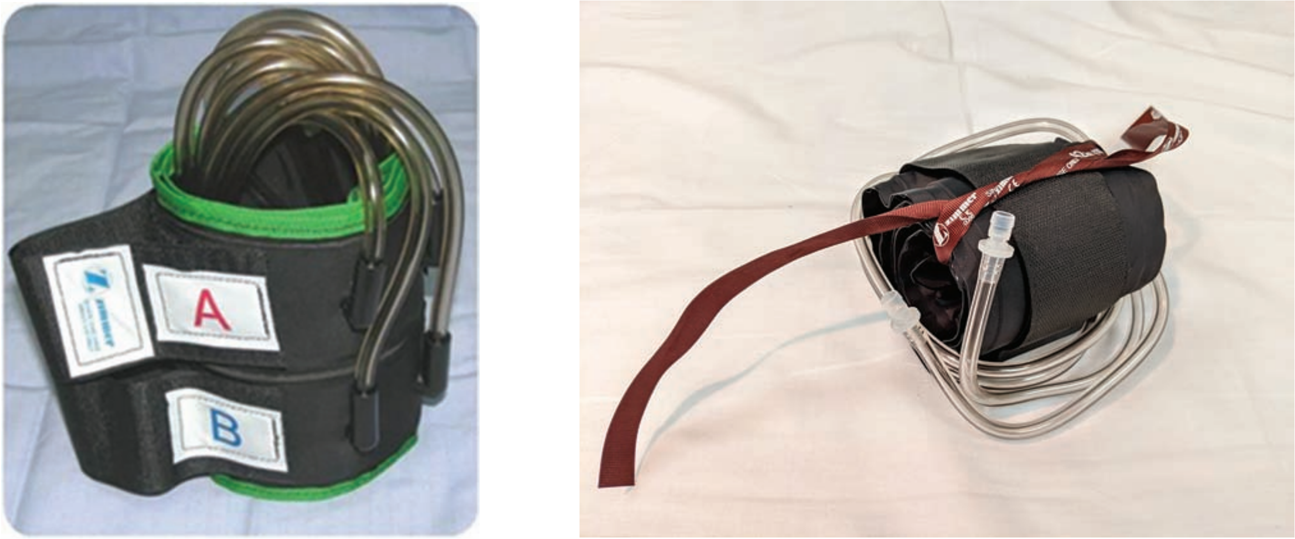


FIGURE 19.3 Dual (*left*) and single-cuff automatic tourniquets (*right*). Historically, these have been used as surgical compressive devices that occlude *arterial* blood flow to the limbs to create a bloodless surgical field and decrease the perioperative blood loss. However, they are also used for IVRA (Bier block) to prevent the central spread of LAs. It is best to inflate the PT after the Esmark elastic bandage wrap exsanguinates the *venous* system in a distal-to-proximal manner over a stockinette.

IVRA, intravenous regional anesthesia; LA, local anesthetic; PT, pneumatic tourniquet.

PROCEDURE

1. Premedication—Some patients may require a benzodiazepine, opioid, or nonopioid medication for anxiolysis and control of pain.
2. Place IV catheters in the injured and uninjured extremities. Dorsal hand of the ipsilateral extremity is preferred.
3. Exsanguination—In all patients, elevation of the injured extremity should occur for at least 3 to 4 minutes. The extremity should be wrapped with an Esmark or elastic bandage to augment the venous exsanguination, although this may be a challenge if it is performed over an injury or fracture. Wrapping should occur in a distal-to-proximal manner, starting at the fingers and ending at the PT. Placing a rolled ACE wrap or webril will aid in protecting the fingers (**FIGURE 19.4**).

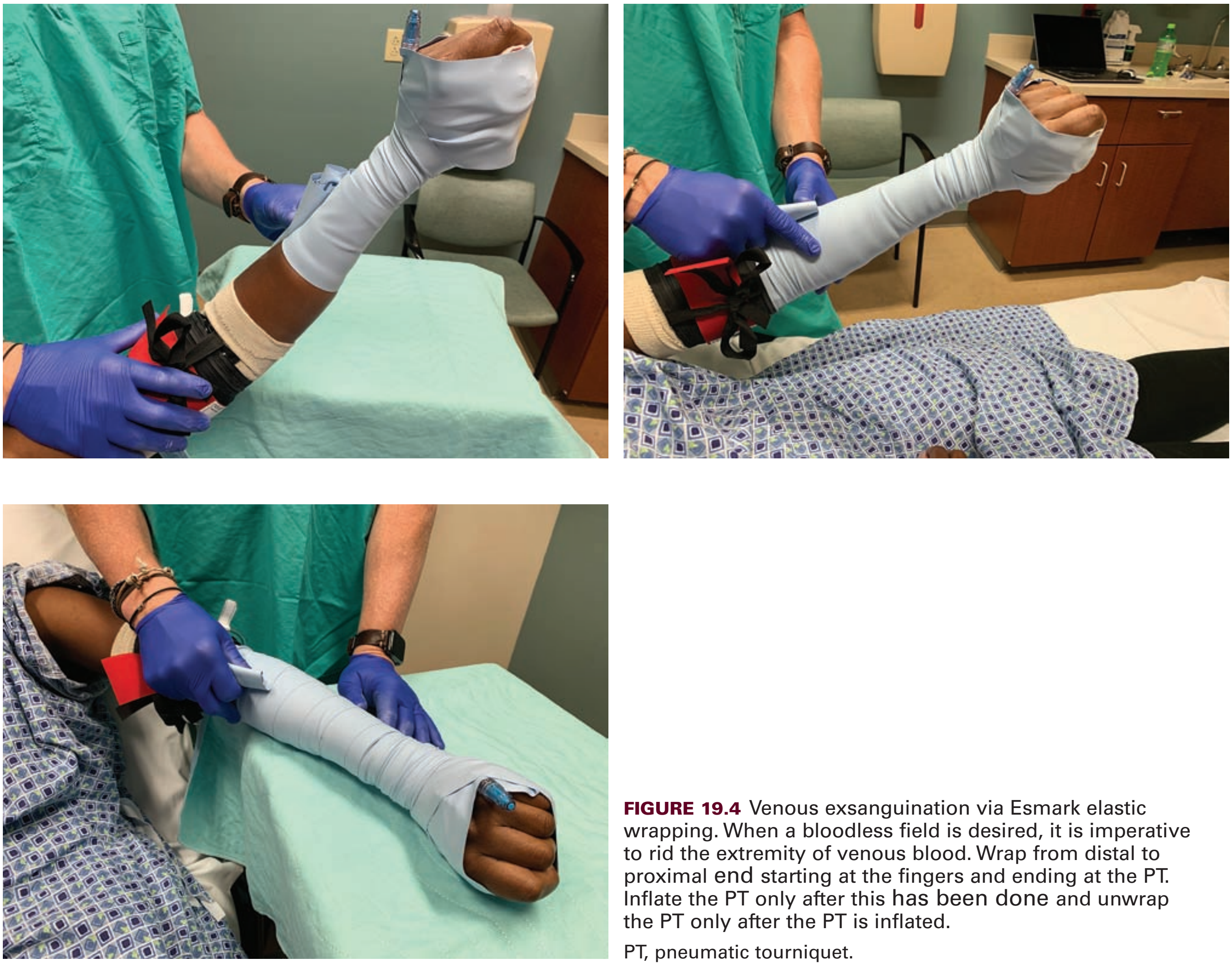


FIGURE 19.4 Venous exsanguination via Esmark elastic wrapping. When a bloodless field is desired, it is imperative to rid the extremity of venous blood. Wrap from distal to proximal end starting at the fingers and ending at the PT. Inflate the PT only after this has been done and unwrap the PT only after the PT is inflated.

PT, pneumatic tourniquet.

4. ***While the Esmark elastic bandage is still wrapped***, inflate the proximal tourniquet to 250 mmHg or 100 mmHg above the systolic blood pressure (SBP; **FIGURES 19.5** and **19.6**). Only when anesthesia is proximally accomplished, inflate the distal cuff. At this point, deflate the proximal cuff. ***Ensure that the distal cuff is inflated before deflating the proximal cuff***. If using two standard BP cuffs, we recommend keeping both cuffs inflated because of an inherently less reliable system. Some recommend increasing the pressure based upon the limb occlusion pressure (LOP), that is, the pressure needed to stop all distal arterial blood flow (SBP) in order to decrease the buildup of ischemic metabolites.
    - Add 40 mmHg for LOP less than130 mmHg
    - Add 60 mmHg for LOP between 131 and 190 mmHg
    - Add 80 mmHg for LOP greater than 190 mmHg

    However, the authors cannot find any evidence for such and recommend a pressure of 250 mmHg or 100 mmHg above the SBP for consistency and simplicity. Some commercial PT systems will have the ability to take a blood pressure and recommend the inflation pressure to use. For children, the PT can be inflated to 50 mmHg above the systolic pressure. A leg tourniquet should be inflated to 300 mmHg or twice the systolic blood pressure. Be aware that in some obese or elderly patients, compression with a PT cannot achieve arterial occlusion due to calcified arteriosclerotic vessels or the large amount of soft tissue surrounding vessels.
5. Unwrap the Esmark elastic bandage from proximal to distal end.
6. ***Ensure there is no arterial blood flow to the extremity; absence of a pulse oximeter waveform from the finger/radial pulse.***

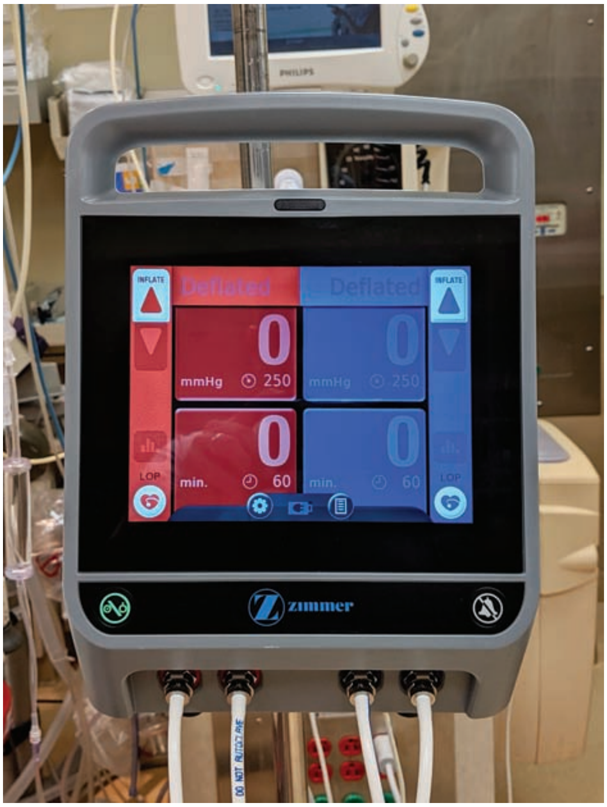


FIGURE 19.5 Portable dual-channel pneumatic tourniquet system. Cuff displays are all color coded for ease of recognition and patient safety. Typically, one enters a desired pressure (250 mmHg) or, in some systems, an LOP is figured out by the machine and a pressure slightly over this is maintained in order to decrease the compressive forces and ischemic sequela. Any decrease in occlusive pressure is noticed immediately and corrected.

LOP, limb occlusion pressure.

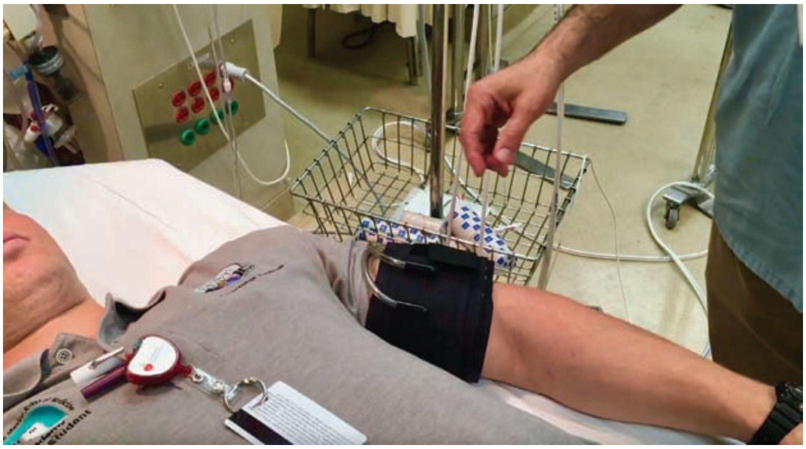


FIGURE 19.6 Tourniquet placement on the upper arm. Note that when applicable, use the PT below the elbow (not shown here) and administer a mini dose of the LA. Only inject after completely wrapping in a distal-to-proximal direction, ensuring absence of arterial flow distal to the PT via absence of a pulse oximeter waveform/radial pulse.

LA, local anesthetic; PT, pneumatic tourniquet.

7. Inject the LA into the IV that was placed in the injured extremity; care must be taken not to inject the LA into the IV placed in the unaffected arm (**FIGURE 19.7**). Administer lidocaine 0.5% (5 mg/mL) in a standard dose of 3 mg/kg or a mini dose of 1.5 mg/kg with the tourniquet below the forearm when possible. For example, in mini dosing, a 70-kg patient will require 105 mg of lidocaine; this is 21 mL of 0.5% lidocaine. With this mini dosing, complete anesthesia should be obtained in 10 to 20 minutes. If anesthesia is incomplete, the patient may be redosed with 1 mg/kg and again if needed with 0.5 mg/kg. ***Do not exceed 3 mg/kg of lidocaine***. It can take up to 15 minutes to achieve full anesthesia.

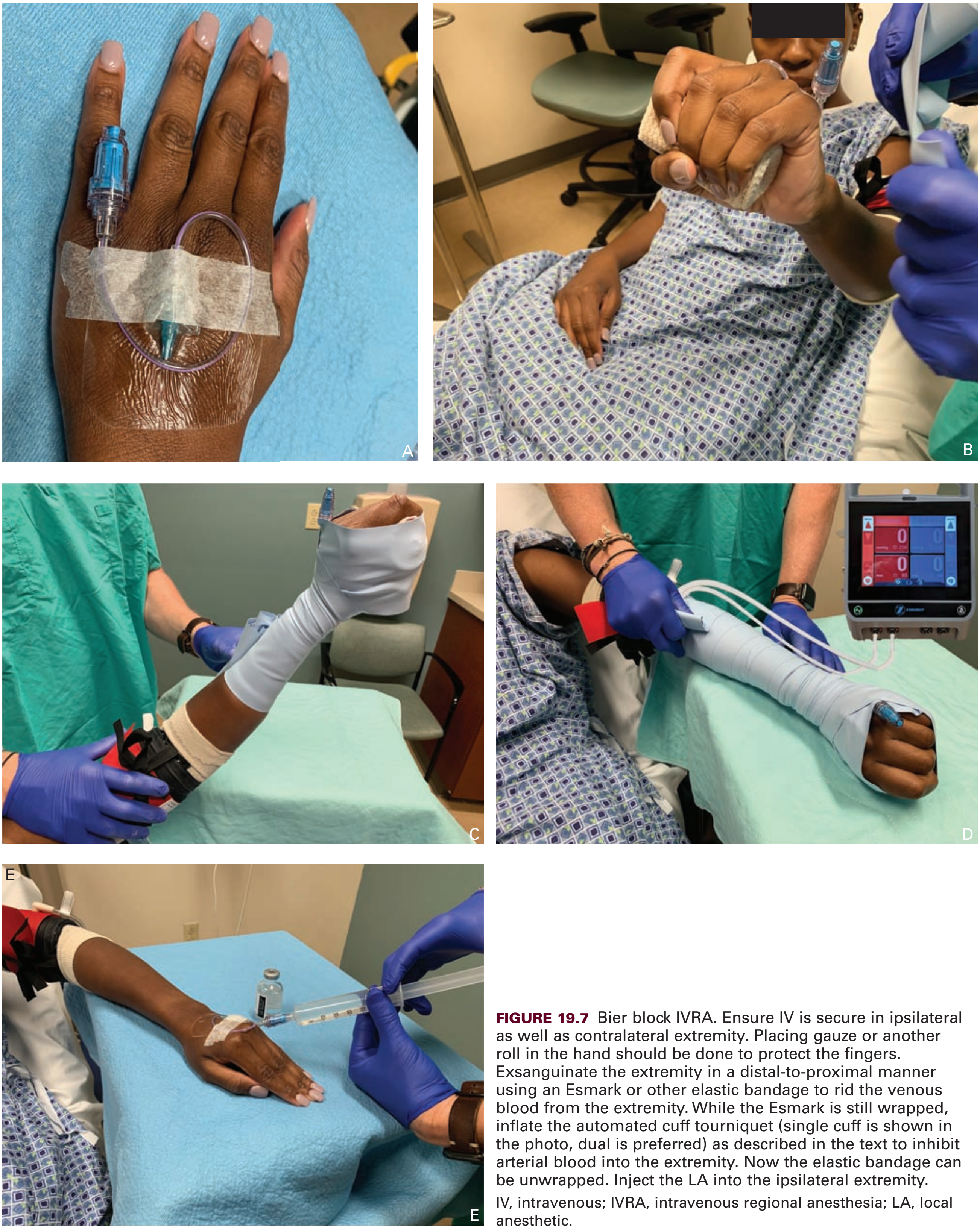

[redacted]

FIGURE 19.7 Bier block IVRA. Ensure IV is secure in ipsilateral as well as contralateral extremity. Placing gauze or another roll in the hand should be done to protect the fingers. Exsanguinate the extremity in a distal-to-proximal manner using an Esmark or other elastic bandage to rid the venous blood from the extremity. While the Esmark is still wrapped, inflate the automated cuff tourniquet (single cuff is shown in the photo, dual is preferred) as described in the text to inhibit arterial blood into the extremity. Now the elastic bandage can be unwrapped. Inject the LA into the ipsilateral extremity.

IV, intravenous; IVRA, intravenous regional anesthesia; LA, local anesthetic.

8. Complete the procedure to be performed.
9. ***Inflation time should be at least 30 minutes to allow complete diffusion of the LA into the tissues so it is not introduced into the systemic circulation once the tourniquet is deflated.***
10. Once 20 to 30 minutes have passed and the procedure is completed, deflate the tourniquet incrementally. It should be deflated in cycles: Five seconds of deflation followed by 1 to 2 minutes of reinflation for three cycles.
11. Observe for signs of LAST; see next section.
12. Discharge once the patient has been observed for 60 minutes.

ULTRASOUND GUIDANCE

Ultrasound guidance may be used to aid in attaining IV access if there is difficulty. It may also assist with the procedure itself such as localization of abscesses, realignment of fractures, or reduction of dislocations.

POSTPROCEDURE CONSIDERATIONS

The patient should be observed for at least 60 minutes posttourniquet deflation to be sure that there are no signs of LAST or other adverse reactions. Postprocedure pain control dosed in the usual fashion for whatever injury the patient has sustained is still necessary. Even when no sedative or opioid medication has been administered, it is still recommended that driving be restricted for 6 to 8 hours postprocedure.

EDUCATIONAL POINTS

- BB IVRA is a safe and efficacious procedure well substantiated and supported in the literature.
- Side effects are rare and no mortality has been reported with the lidocaine *without* epinephrine as the LA.
- The mini dose of lidocaine (1.5 mg/kg) for IVRA is just about the same dose given to treat cardiac dysrhythmias.
- Though one should always check to ensure there is an absence of a radial pulse before injecting the LA, the literature is clear that using a pulse oximeter displaying an absence of a waveform is more reliable and accurate.
- Using the mini dose LA, typical volumes for upper extremities are less than 50 mLs, whereas those for lower extremities are usually greater than 50 mLs.
- Limit tourniquet time to less than 90 minutes.
- Only inject the LA after the PT has been fully inflated and the pressure verified.
- Ensure that the extremity is exsanguinated to allow more of the LA to fill the vasculature and to decrease bleeding.
- Safeguard that the IV is placed at least 10 cm distal to the inflated cuff to ensure no proximal infusion under the cuff and into the systemic circulation; very distal IV placement may actually increase the anesthesia as the mechanism of action is that of a diffusion of the LA out of the capillaries and into the tissues and, specifically, the sensory and motor nerves.
- Cycle the deflation/inflation of the cuff three times (deflate for 5 seconds and then reinflate the cuff for 1 to 2 minutes before repeating these steps); this is done as a precautionary measure to guard against any LA that may have been left in the vasculature and hence prevent potential bolus effect of the LA into the systemic circulation.
- Despite the duration of the procedure, ensure a cuff time of 30 minutes at a minimum in order to safeguard all/most of the LA diffused across the capillaries and hence out of the vasculature and into the tissues; if cuff time is less, a bolus effect may occur.
- A portable DCATS is the preferred equipment and standard of care.
- ***It is imperative to inflate the distal cuff before the proximal cuff is released; otherwise, the LA will rapidly diffuse into the systemic circulation.***

COMPLICATIONS

Most complications are minor and are related to the use of LAs. Lidocaine generally causes neurological symptoms before cardiovascular ones, so stop immediately if any of the former ensue. The most common reported adverse reactions are:

- Tongue and perioral numbness
- Lightheadedness
- Tinnitus
- Muscular twitching
- Nausea
- Vomiting

Very rarely there may be serious complications that are usually due to the release of a large amount of LA into the systemic circulation. LAST syndrome includes:

- Altered mentation
- Seizures
- Brady dysrhythmias
- Apnea
- Cardiovascular collapse

Treatment should be instituted with standard resuscitation techniques, including cardiac monitoring, oxygen, IV fluids, and benzodiazepines in case of seizure.

- Lipid emulsion therapy is a treatment option for LA-induced (especially bupivacaine as it has a longer half-life) cardiovascular toxicity, although large prospective blinded studies are lacking.

Possible mechanisms of action include:

- Creation of a lipid sink in which highly fat-soluble LAs (particularly bupivacaine) are absorbed from the aqueous plasma phase into the lipid phase of plasma from tissues (e.g., the heart) affected by LA-induced toxicity
- Enhanced redistribution (lipid shuttle)

In general, lidocaine has a relatively short half-life, causes more neurotoxicity than cardiovascular toxicity, and is responsive to benzodiazepine therapy. Bupivacaine has a longer half-life, causes more cardiovascular toxicity than neurotoxicity and, as such, is not recommended for IVRA.

Mechanical complications due to the use of a tourniquet are also common and include:

- Tourniquet-related pain
- Petechiae in the affected extremity
- Thrombophlebitis

PEARLS

- IVRA is safe and underutilized, especially in large/multiple lacerations, burns, and fractures.
- Best treatment of LAST is prevention; calculate and verify dose of the LA; do not exceed 3 mg/kg of lidocaine.
- It is common to immediately see a mottled and dusky extremity after injection of the LA.
- General resuscitation equipment should be readily available for safety.
- A properly prepared LAST cart with a benzodiazepine and intralipid emulsion should be readily available.
- As a rule of thumb, treat neurotoxicity with benzodiazepines and cardiovascular toxicity with advanced cardiac life support (ACLS) and lipid emulsion therapy.
- Commercially available DCATS are superior to standard BP cuffs.
- Procedures are best done in a bloodless field; for this reason, the use of an Esmark elastic bandage applied distal to the pneumatic cuff, wrapping from the distal fingers in a proximal direction to the pneumatic cuff in an effort to rid the venous blood from the extremity, cannot be overemphasized before inflating the cuff.
- ***Esmark elastic bandage rids venous blood from the extremity; the pneumatic cuff rids arterial blood from the extremity.***
- Confirm proper tourniquet inflation and absence of a radial pulse before injecting of LA.
- Use the mini dose of lidocaine (1.5 mg/kg) with a forearm tourniquet when feasible.
- The toxic dose of lidocaine without epinephrine is 4 mg/kg.
- Lower extremity PTs should not be inflated above the mid-calf to avoid peroneal nerve injury.
- Skin blanching during injection is common and likely the result of blood extravasation from capillaries as it is displaced by LA; it does not signify an allergic reaction.
- Do not deflate a PT less than 30 minutes after the procedure in order to allow complete diffusion of the LA into the tissues and to avoid its release into the systemic circulation.
- Observe for 1 hour postprocedure for signs of LA toxicity.
- ***Bupivacaine is contraindicated secondary to its increased cardiovascular toxicity and longer half-life (see Chapter 16, Anesthetic Agents and Procedures for Local and Field Infiltration).***

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CHAPTER 20

Procedures for Performing Auricular Anesthesia

Brian Parker and Theresa M. Campo

BACKGROUND

Anesthesia for the external ear, also known as *auricular blocks* or *auricular anesthesia*, can be used to treat extensive lacerations, auricular hematomas, and other painful procedures to the external ear.

The ear, also known as the *auricle*, is divided into three areas: external, middle, and internal structures. Discussion here is limited to the external auricle. The external ear is innervated by four branches of nerves: the greater auricular nerve (branches off from the cervical plexus), lesser occipital nerve, auricular branch of the vagus nerve, and auriculotemporal nerve (**TABLE 20.1** and **FIGURE 20.1**).

PATIENT PRESENTATION

- Lacerations to the external ear or skin surrounding the ear
- Incision and drainage of an abscess or hematoma

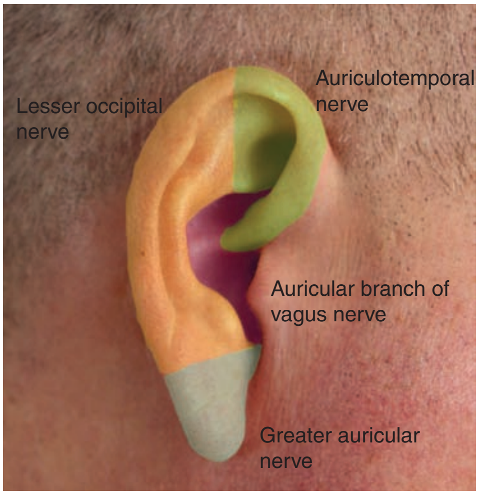

FIGURE 20.1 Nerve innervations of the ear.

TABLE 20.1 **Auricular Nerve Branch and Innervation**

Nerve Branch	Innervation
Greater auricular nerve (branch of cervical plexus)	Posteromedial, posterolateral, and inferior auricle
Lesser occipital nerve (branch of cervical plexus)	Few branches may contribute to posteromedial, posterolateral, and inferior auricle
Auricular branch of vagus nerve (CN X)	Concha, most of the auditory meatus, tympanic membrane
Auriculotemporal nerve (mandibular branch of trigeminal nerve, CN V)	Anterosuperior and anteromedial auricle

CN, cranial nerve.

TREATMENT

Local anesthetic agents can be utilized when performing an auricular block with or without epinephrine. However, epinephrine is contraindicated for any direct infiltration of the ear. One should allow approximately 10 minutes before proceeding with the procedure once the block is performed. Always test the area to ensure adequate anesthesia.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Cellulitis
- Severe allergy to anesthetic agent

PROCEDURE PREPARATION

- Syringe (10 mL)
- Lidocaine 1% or bupivacaine 0.25% (epinephrine should *not* be used for direct infiltration of the ear/auricle)
- Needle—25 to 30 gauge

PROCEDURE

- Cleanse the area for infiltration with skin cleanser.
- Fill the 10-mL syringe with either lidocaine or bupivacaine.
- Attach the needle to the syringe. Injection site depends on the portion of the ear requiring anesthesia. **TABLE 20.1** lists the nerve branches and the areas innervated by each branch.

Local Nerve Branch Blocks

These are for the greater auricular and lesser occipital nerve branches.

- Insert needle at the posterior sulcus, pointing to the superior pole, following the curve of the auricle (**FIGURE 20.2**).
- Gently aspirate and then inject 3 to 4 mL of anesthetic block.

Auriculotemporal Nerve Branch

- Insert needle superior and anterior to the tragus.
- Gently aspirate and then inject 2 to 4 mL of anesthetic (**FIGURE 20.3**).

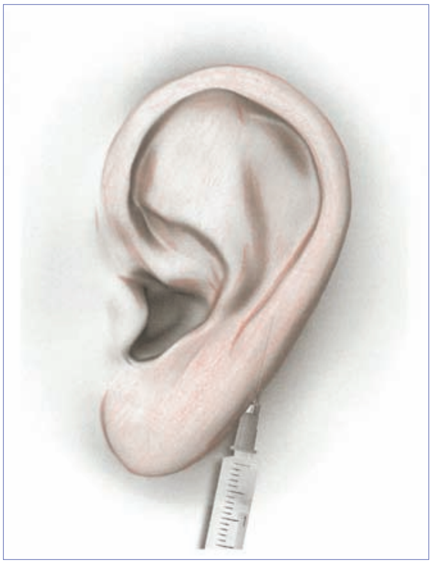

FIGURE 20.2 Local nerve block for greater auricular and lesser occipital nerve blocks.

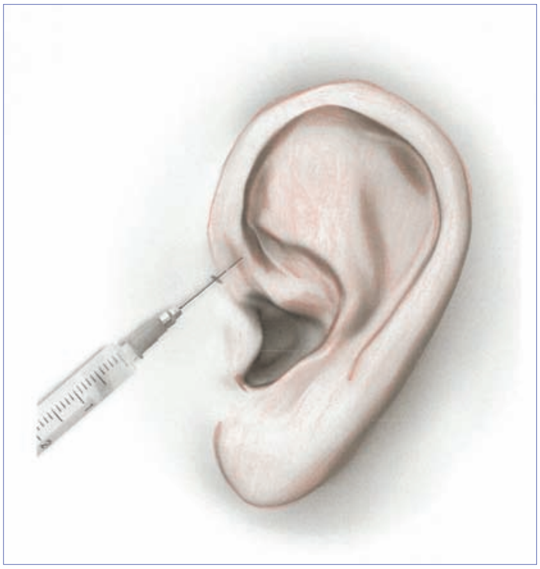

FIGURE 20.3 Local nerve block for auriculotemporal nerve block.

Ring Block/Regional Block

- Insert the needle subcutaneously approximately 1 cm superior to the auricle, just anterior to the tragus.
- Gently aspirate and then inject 3 to 4 mL of anesthetic.
- Remove the needle.
- Insert the needle into the same place but direct it posteriorly.
- Gently aspirate and then inject 3 to 4 mL of anesthetic.
- Remove the needle.
- Insert the needle inferior to the ear lobule.
- Repeat the aforementioned steps, injecting anteriorly and posteriorly (**FIGURE 20.4**).

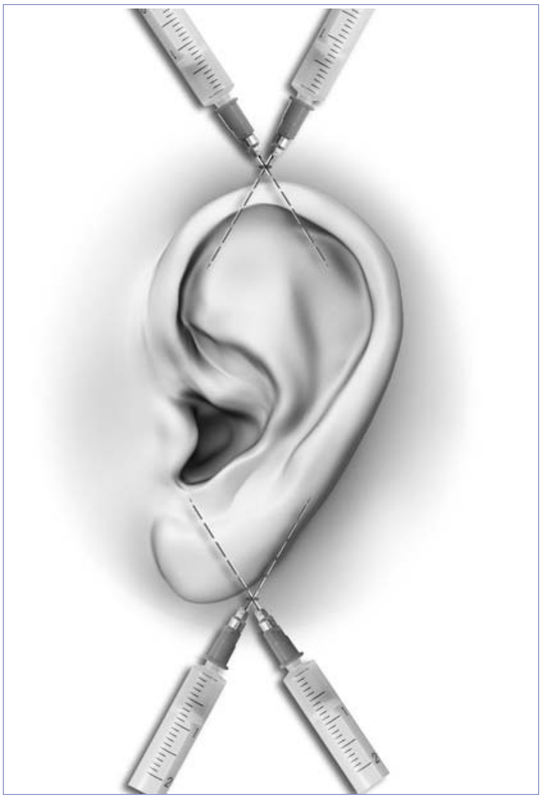

FIGURE 20.4 Ring-region nerve block of the ear.

ULTRASOUND GUIDANCE

There is a growing body of evidence that high-resolution ultrasound can be used to identify the greater auricular nerve to improve accuracy of anesthesia. Despite use of this modality, auricular anesthesia is still primarily a landmark-based procedure.

POSTPROCEDURE CONSIDERATIONS

- Pain with injection of anesthetic
- Consult ear, nose, and throat (ENT) specialist with any concerns

COMPLICATIONS

- Possible cannulation of the superficial facial artery
- Hematoma
- Accidental phrenic nerve block
- Transient paralysis of shoulder shrug maneuver

PEARLS

- The use of lidocaine with epinephrine has generally been contraindicated for the outer ear. However, recent literature suggests that the use of epinephrine does not block the circulation to this area of the ear and, therefore, does not cause necrosis.
- Over 60 years ago, epinephrine was used only with the anesthetics procaine and cocaine, and necrosis was found to occur. However, it was later discovered that it was the acidity of the anesthetics (especially procaine), not the epinephrine, that caused the necrosis.
- The decision to use epinephrine for local infiltration of the outer ear is at the clinician's discretion and should be based on the most up-to-date evidence-based practice. Epinephrine is also acceptable for regional block of the ear. Consider consultation with an ear, nose, and throat (ENT) specialist for assistance in managing a patient injury/insult that requires anesthesia.

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UNIT VII

Skin and Wound Management Procedures

CHAPTER 21

Overview of Wound Healing and Soft-Tissue Ultrasound

Susanna Rudy

BACKGROUND

Soft tissue consists of the skin, adipose, muscles, nerves, and blood vessels. Skin is the largest and fastest growing organ of the human body, comprising approximately 8 lbs. or 22 sq. ft of body surface area. There are multiple functioning layers to skin; collectively, they are the first line of defense in injury. Although skin is tough, pliable, and regenerative, all areas of the skin surface are prone to injury when trauma occurs. Risk of injury increases with exposure; type of environment; and the mechanism, impact, and duration of the energy source.

Soft-tissue injury may be a primary presenting critical illness. In addition, injury to the soft tissue can contribute to overall clinical management. The natural ability to heal skin wounds is a complex and multifactorial restorative process that relies on soft-tissue functions of skin, muscles, nerves, and blood vessels. After an insult or injury, the immune response is activated, initiating the processes of cellular reconstruction and restoration of anatomical structures involving inflammation, coagulation, angiogenesis, fibroplasia, contraction, epithelialization, and remodeling.

Skin is a component of the integumentary system. It is a complex organ consisting of the epidermis, dermis, and skin appendages, including the hair follicle and sebaceous gland, and is technically known as the *cutaneous membrane*. The cutaneous membrane consists of three major areas: cutaneous (epidermis), subcutaneous (dermis), and deep fascia. The role of skin is to protect the internal organs, bones, tendons, ligaments, tissues, and structures from external forces: Physical, chemical, radiological, or biological hazards that would cause injury or damage. Skin is our natural armor. In addition to protection, skin plays a key role in regulating vital body functions. The skin helps with excretion of waste (urea, salts, water) through perspiration; temperature regulation through vascular vasoconstriction, vasodilation, and perspiration; sensation of pain, pressure, and thermal sensory perception through intricate networks of nerve endings and sensory fibers; and the synthesis of vitamin D, an essential biohormone, when exposed to sunlight. The skin also acts as a water barrier, specifically, the stratum epithelial layer. Disruption of this layer can result in large water loss in addition to normal insensible water loss, particularly in burn patients.

Layers of Protection

The cutaneous layer comprises the epidermal and dermal layers. The epidermis is the outer layer of the skin and is made up of stratified squamous epithelial cells and dead skin cells filled with keratin. It is the most visible and is the first layer of defense. It is composed of thin layers of skin cells responsible for immunity and regeneration of new skin cells; it also houses melanin, the group of pigments produced in melanocytes found in the basal stratum, or bottom layer, of the epidermis. Epidermal production of melanin produces the natural color variations in human skin.

The epidermis is also home to important microorganisms that live relatively benign lives in a commensal relationship with their human hosts. *Staphylococcus epidermidis* and *S. aureus* are important opportunistic pathogens that are permanent and ubiquitous colonizers of human skin. *S. epidermis* is the most frequent flora isolated from human epithelia. These microorganisms also represent the most common pathogens causing nosocomial infections related to indwelling medical devices and septic shock. The infiltration of these pathogens past the epidermal layer, antibiotic and habitat-resistant gene mutations, the formation of biofilms, pathogen virulence, and host immunity are all high-risk factors for the development of acute life-threatening infection and/or chronic disease. The breach or malfunction of the processes that create the first layer of skin defense, allowing for passage of microflora into the deeper structures, can result in infection, healthcare-related expenses, and life-threatening illness.

There are two layers in the epidermis that are most important to wound healing: the stratum corneum and the stratum germinativum. The stratum corneum (horny or keratinized layer) is progressively pushed up from the stratum basal layer. This layer is very thin (0.2-mm thick) and difficult to differentiate from the stratum basal and dermal layer. The stratum germinativum (stratum basale), which is the deepest layer of cells, is responsible for the regeneration of stratum corneum. This layer consists of Merkel cells, melanocytes, and stem cells that are continually regenerating new keratinocytes as old ones are shed.

The dermis is the main component of the wound-healing process. It is thicker, lies below the epidermis, and is made up primarily of connective tissue. The main cells of the dermis are fibroblasts, which are key in the facilitation of wound healing. They deposit fibrous proteins (elastin fibers and collagen) that give the wound its intrinsic tensile strength. Blood vessels, nerves, and sebaceous and sudoriferous glands are contained within the loose connective tissue of this layer.

The hypodermis (subcutaneous, superficial fascia, subcutis) is the layer that lies directly between the dermis and the skeletal muscle. It is primarily composed of loose connective and adipose tissue responsible for thermal regulation and shock absorption. During trauma and significant temperature changes, these tissues provide insulation and protection to major blood vessels and underlying structures. Sensory nerves and major blood vessels pass through this layer. The subcutaneous layers house collagen, a vital protein that forms the scaffolding necessary for restoring elasticity and integumentary tensile strength of a wound.

The fascial layer is the deepest layer of the cutaneous membrane (skin). It is composed of fibrous, thick, and dense tissue that supports the superficial layers of the skin. This layer contains sensory nerve fibers, blood vessels, and lymphatics. The functions of this layer are to promote protection from the spread of infection as well as to support and protect the underlying muscle and soft-tissue structure. See **FIGURES 21.1**, **21.2**, and **21.3** for the layers of the skin, muscles, and fascia.

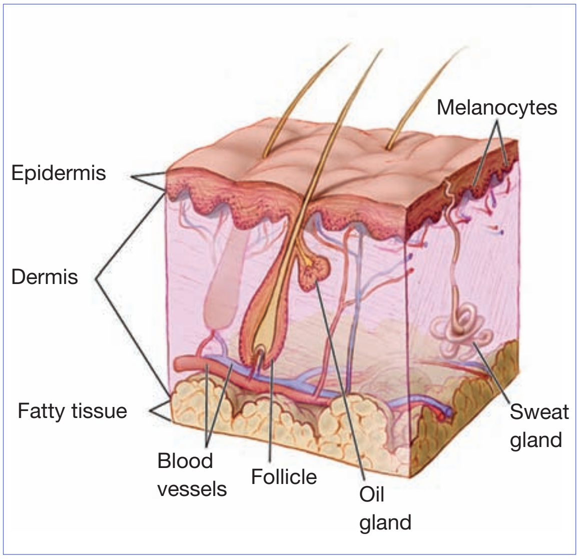


FIGURE 21.1 Skin anatomy.

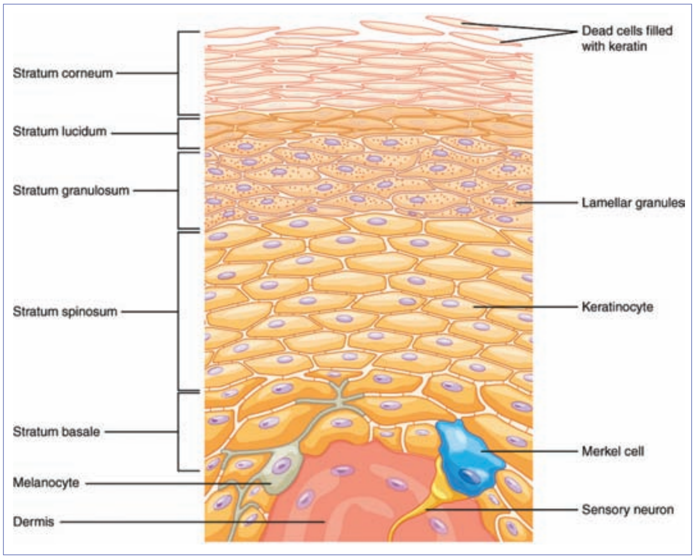


FIGURE 21.2 Layers of epidermis.

Source: Reproduced from Layers of the skin. (n.d.). *Anatomy and physiology*. Retrieved from https://opentextbc.ca/anatomyandphysiology/chapter/5-1-layers-of-the-skin

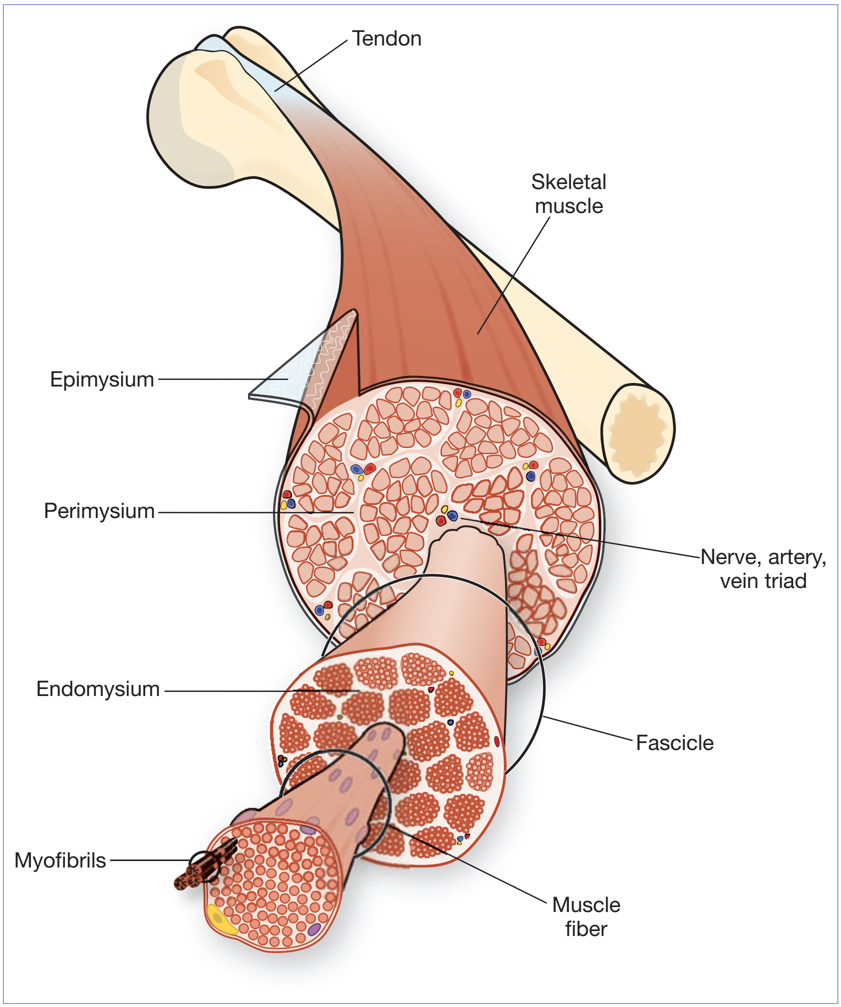


FIGURE 21.3 Structure of skeletal muscle.

Types of Wounds

There are generally six categories of wounds: abrasion, avulsion, combination, crush, laceration, and puncture. The characteristics and extent of the wound are dependent on the causative force. See **TABLE 21.1** for a more complete description of wounds and injuries that can occur.

TABLE 21.1 Description and Type of Soft-Tissue and Skin Wounds

Type of Injury	Mechanics (Force)	Wound Characteristics	Examples of Causes
Contusion	Blunt (closed) Tensile Compression Impact with force	Hematoma, ecchymosis, swelling, may have concominant abrasions	Bruising Bumping knee or elbow, punch to body, blunt-force trauma without laceration Blow to the head
Abrasion	Skin and object impact in opposite directions Skin rubs or brushes against a hard surface	Superficial removal of epidermis: scrapes, graze Rough appearance with loss of epidermis and superficial dermis	Superficial scrapes of hands and knees: sliding fall onto hard or rough surface, floor or rug burns Baseball slide "Strawberry," "road rash"

(*continued*)

TABLE 21.1 Description and Type of Soft-Tissue and Skin Wounds (*continued*)

Type of Injury	Mechanics (Force)	Wound Characteristics	Examples of Causes
Avulsion	Shearing tensile forces Tears, body structure is detached at normal insertion point	Avulsion of skin, partial or complete loss of skin layers Degloving Amputation	Extremities caught in machinery, turbines; skin tear, torn limb, or ripped tissue, flap of skin
Puncture	Tensile compression	Small entrance wound Depth of wound is greater than width, creates a track and unable to visualize end of the wound	Icepick, nails, needles, splinters, darts, punch to the mouth with tooth puncture
Laceration	Shear, compression, tensile Incisional: intentional or traumatic Cuts, gashes, stab wounds, surgical incisions Clean sharp object	Penetrates through the epidermis into dermis and beyond Linear or stellate Clean, tidy, rough, or jagged	Glass splinter Knife, razor Striking face, head on stationary object
Occupational	Machinery Occupational hazards	Amputation, avulsion, devitalized tissue, burning, high-pressure injections	Paint gun Compressor Power washer Nail gun Projectile
Foreign body	Projectile, impalement Penetrating Ballistic	Entry wound Alteration in skin surrounding entry wound May not be grossly visible	Gunshot wound High velocity, pellet or BB gun Arrow, spear, or flying objects
Crush, shear, tensile	Blunt Penetrating Concussive	Takes on numerous appearances depending on the forces associated Abrasions Scleral injection Petechial hemorrhaging Contusions	Explosions Airbag deployment Motor vehicle crash
Compression/crush	Compression of tissue against hard surface or bone Extreme force over a period of time	Devitalized tissue Ecchymosis surrounding wound Swelling Concern for compartment syndrome and hyperkalemia, rhabdomyolysis	Pinned against a hard object Object falls from height onto body
Shearing Tensile Environmental Exposures	Pharmacological ingestions Thermal, chemical, biological, irritants, pH altering Water, steam, dirt, wind	Burns Redness Blistering Excessive tearing FB in the eye Loss of dermal integrity, sloughing Ulcers, rashes	Steam burn Cooking burns CBRNE exposure Infectious disease exposure

CBRNE, chemical, biological, radiological, nuclear, and explosives; FB, foreign body.

Wound Healing

Immediately following injury, the body naturally attempts to heal itself. This innate process of wound healing follows an ordered timeline of complex and interwoven physiologic responses in order to repair itself following insult or trauma. The steps involved in this process include:

- Inflammation
- The fibroblastic phase
- Scar maturation
- Wound contracture

PHASES OF WOUND HEALING

There are three main phases to wound healing:

- Inflammation
    - Homeostasis
    - Inflammation
- Proliferation
- Remodeling

During wound healing, there are many events that occur separately and simultaneously. These begin at the onset of the wound and can continue for 1 to 2 years.

Homeostasis begins minutes after the injury via vasoconstriction, activation of the clotting cascade, and platelet aggregation. The platelets release thrombin and growth factors that attract fibroblasts and monocytes to the wound, activating the intrinsic clotting cascade. This helps to limit the initial damage of the wound by ceasing bleeding and sealing the wound surface through retraction of the wound edges and clot formation.

The inflammatory phase is characterized by activation of the complement system, which causes increased vascular permeability, migration of cells into the wound, and angiogenesis. Clinically, this constitutes the physical findings of erythema, swelling, warmth, and pain often present with soft-tissue injury. Chemoattractant agents bring the neutrophils and monocytes to the wound within 24 to 48 hours. The neutrophils clean the area by trapping and killing bacteria. The monocytes become tissue macrophages that produce growth factors and cytokines to remove nonviable tissue and bacteria. Epidermal cells begin to migrate into the wound from surrounding tissues.

Neovascularization, fibroplasia, and epithelialization are the main components of the proliferation phase. Granulation occurs during this phase and the wound edges move closer together. A loose arrangement of collagen fibers begins to fill the wound as new capillaries begin to grow.

During the maturation phase, remodeling of the wound and contraction begin to occur. Wound contraction occurs as a result of myofibroblasts pulling collagen toward the cell body and epithelization is the migration of epithelial cells to resurface the wound. A more organized and stable form of collagen replaces the soft collagen. This increases the intrinsic tensile strength of the wound. This phase usually lasts about a year but can take 2 years to complete. Healed wounds never regain their original strength after injury. Approximately 1 week after the wound occurs, the tensile strength may be around 10% and after 1 year it can be 80%.

TYPES OF WOUND HEALING

Wound healing can occur in one of three ways:

- Primary intention
- Secondary intention
- Tertiary intention

Primary, or first, intention wound healing occurs in wounds that are clean and have limited tissue loss; the wound edges can easily approximate, and can be closed using surgical wound-closure techniques. Sutures are the standard of care for linear laceration closures. The choice of suture (absorbable, nonabsorbable) depends on the location, type of wound, depth, degree of tension required, and desired cosmetic outcome. Staples are an alternative closure type used in scalp or extremity wounds. Steri-strips, topical skin adhesives (glues), and adhesive tape are associated with decreased inflammation and infection rates. The ability to close wounds depends on time of initial injury, level of contamination, and amount of tissue devitalization present/wound edge dehiscence. Primary intention wounds are either clean lacerations or surgical incisions.

Secondary-intention wounds are those with larger areas of tissue loss, gross contamination, and defect of the soft tissues such as ulcerations, abscess wounds, puncture wounds, human and animal bites, or surgical wounds requiring extensive debridement. These wounds are left open, allowing the granulation process of the regenerative phase to heal the wound from inside out. Contraction and epithelialization eventually close the wound, resulting in scar formation. Puncture wounds from foreign bodies, animal bites, and lacerations with devitalized skin from blunt trauma are high-risk wounds for the development of secondary infection if closed using primary techniques. These wounds should be thoroughly cleaned and debrided. They can be allowed to heal naturally or closed at a later time (delayed primary closure).

Tertiary intention, or delayed primary closure, can be considered for wounds initially treated with secondary intention. These types of wounds should be left open for a minimum of 3 to 5 days to improve blood flow to the wound edges for improved approximation and to allow for the granulation process (proliferation phase), which decreases the risk of infection. The wound can be closed when thoroughly cleaned by primary closure or by incising the wound margins to create a fresh laceration. A wound vacuum-assisted closure (VAC) device can also be used for those wounds requiring delayed closure; it prepares the wound bed by using negative pressure over the wound to decrease edema and size in preparation for delayed closure. Delayed closures can occur weeks or months after the initial injury.

FACTORS COMPLICATING WOUND HEALING

Wound healing is a complex process that can be affected by numerous factors. Trauma, extent of the wound, patient age, type of closure, alcoholism, diabetes, connective tissue disorders, medications, vitamin deficiencies, nutritional status, and circulation are all factors that affect wound healing. The aging process gradually inhibits cellular activity responsible for cell regeneration, leading to weakened structural integrity and thinning. Trauma, shock, or a stress or pain response can potentiate a sympathetic catecholamine surge, resulting in vasoconstriction and decreased perfusion, which have global implications for wound healing. Hypothermia impairs wound healing and resistance to infection. Thermoregulatory vasoconstriction decreases tissue perfusion and the local oxygen partial pressure necessary for wound healing and infection prevention. Mild hypothermia has been shown to impair the immune response by impairing the phagocytic and oxidative killing by neutrophils. Consideration of underlying factors and prevention of further damage to the wound during any interventions are key to efficient wound healing.

WOUND CARE

Wound care before and after any procedure is crucial to wound healing. All wounds require cleansing with sterile normal saline, sterile water, or tap water. This can be completed through irrigation, high-pressure irrigation, scrubbing, and soaking. The method used will depend on the type and extent of the contamination of the wound. The use of hydrogen peroxide and povidone-iodine are no longer recommended as they cause damage to the viable tissue from oxidation. Any time these substances are used, they should be diluted (povidone-iodine has been shown to be effective and not tissue toxic if diluted in a 10:1 manner with saline). Skin cleansers should also be used on intact skin before any invasive procedure (suturing) to limit contamination.

WOUND MANAGEMENT

All wounds presented in this book should be treated with general care. Cleaning the skin with a skin cleanser (diluted povidone-iodine or chlorhexidine) should be done before any injection procedure. Remember, the solution for pollution is dilution. Open wounds should always be irrigated with 0.9% normal saline before progressing with any procedure. It would be redundant to list this step for each procedure involving an open wound. If a specific method of wound cleaning is necessary, it will be noted in the respective chapters.

ASSESSMENT OF SOFT TISSUE WITH POINT-OF-CARE ULTRASOUND

Soft-Tissue Ultrasonography

Ultrasound has become a primary diagnostic tool in inflammatory, degenerative, or traumatic soft-tissue pathology. The indications for performing a musculoskeletal or soft-tissue ultrasound include trauma, signs of infection, bruising or inflammation, or general suspicion of underlying pathology in a patient who presents with pain. The use of ultrasonography to identify soft-tissue infections and foreign bodies is becoming more widely utilized in the emergency, urgent, and primary care settings. Ultrasound can be useful in identifying cellulitis, necrotizing fasciitis, abscess, and retained foreign bodies. It is important to identify the normal structures of tissues before discussing ultrasound-guided procedures specifically. The equipment, techniques, and normal anatomy of soft tissue are discussed in this section.

Probe Selection

A high-frequency linear array transducer is the ideal probe suitable for most musculoskeletal and soft-tissue applications. Linear probes are high frequency, operating at a level of approximately 5 to 13 MHz, with ultrasonic focusing at a depth up to 7 cm. Images demonstrate high resolution for shallow structures. The image footprint is shaped like the probe: narrow and rectangular. If the patient has a larger body habitus, or structures of interest are deeper and require a broader view, the lower frequency probe—a curvilinear, or abdominal, probe—has frequencies of 1 to 5 MHz, allowing deeper penetration and resulting in a wider pie-shaped image at the expense of clear resolution. The musculoskeletal, vascular, nerve, or small structures exam type is chosen to evaluate the structures within the skin and soft tissues (**see FIGURES 21.4** and **21.5**).

Linear probe: Has a frequency of 5 to 12 MHz, high resolution, and provides superficial penetration up to 7 cm.

Low-frequency probe: Curvilinear or abdominal probe: Has a frequency of 1 to 5 MHz, is low resolution, but offers deeper penetration, up to 36 cm. Useful for large body surface area evaluation in patients with larger body habitus.

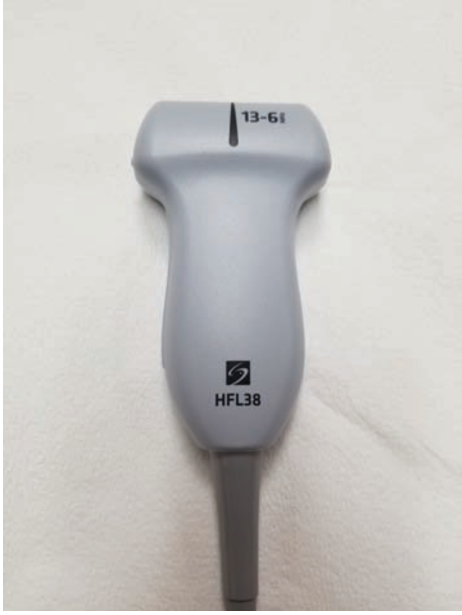


FIGURE 21.4 High-frequency linear probe.

Source: Courtesy of Sonosite. Photo by Susanna Rudy.

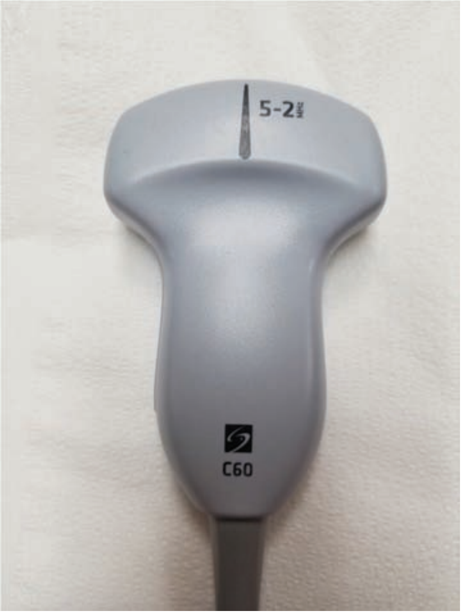
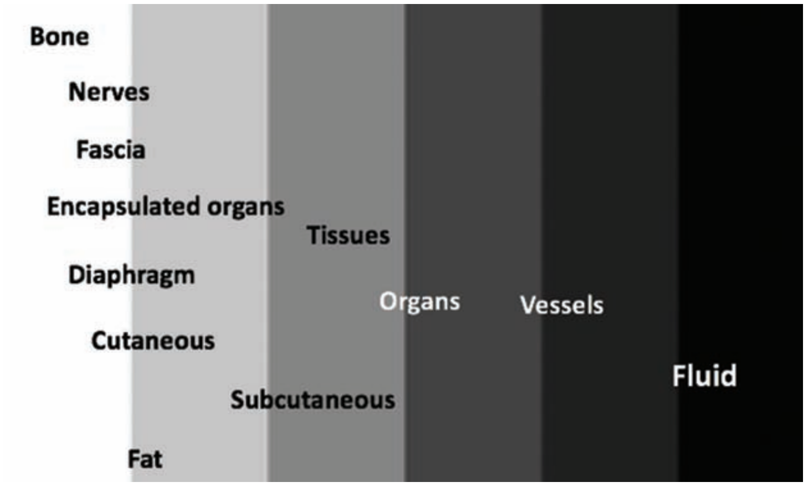


FIGURE 21.5 Low-frequency curvilinear (abdominal) probe.

Source: Courtesy of Sonosite. Photo by Susanna Rudy.

Echogenicity Overview

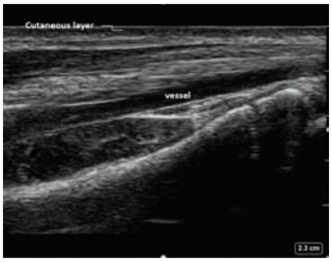
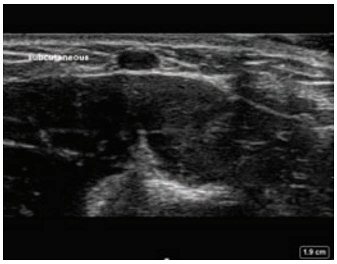
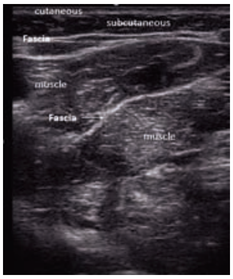
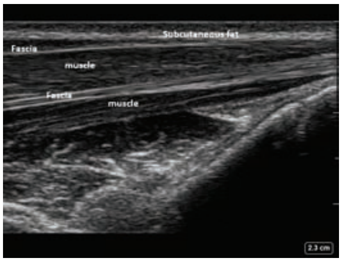
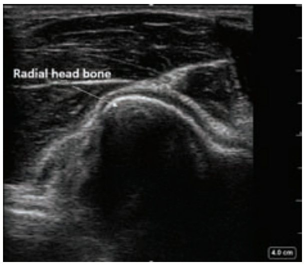
Echogenicity: Various body tissues refract, reflect, dissipate, or return sound waves at different speeds based on their density. The amount of returning sound wave echoes dictates the image formation. The denser the material, the more those echoes are reflected and return to the probe and are translated into an image by the machine. White dots are plotted on a black background on a transitional scale of 256 shades of gray (**FIGURE 21.6**). Soft tissues are compared to each other and form consistent characteristics in comparison to surrounding structures, organs, inflammation, or foreign bodies (**TABLE 21.2**).


Bone
Nerves
Fascia
Encapsulated organs
Tissues
Diaphragm
Organs
Vessels
Cutaneous
Fluid
Subcutaneous
Fat

← Hyperechoic	Isoechoic	Hypoechoic	Anechoic →
← Echoes return	Echoes reflected, refracted, attenuated		Echoes absorbed →

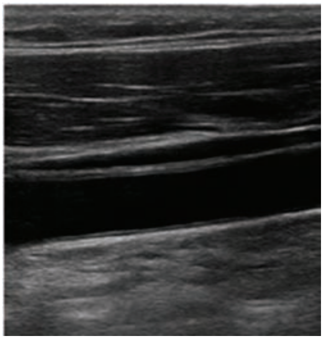
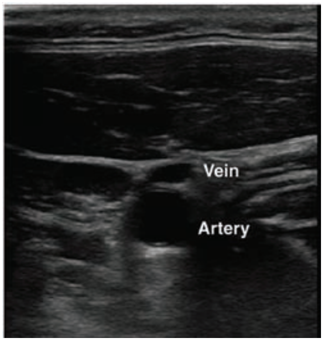
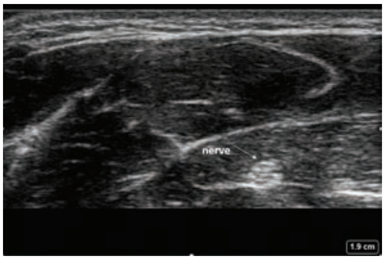
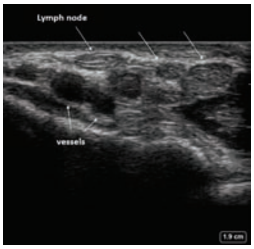
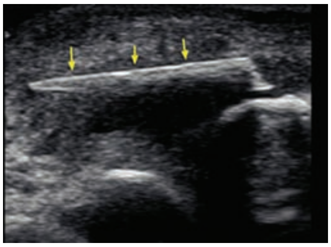
FIGURE 21.6 Ultrasound echogenicity based on varied densities.

TABLE 21.2 Layers of Soft Tissue With Ultrasound Imaging

Tissue Layer	Tissue Echogenicity	Appearance	Normal
Cutaneous (epidermis and dermis)	Hyperechoic	Thin and regular, the epidermis and dermis are indistinguishable by ultrasound, and appear as a single thin, bright layer	 Cutaneous layer vessel 2.3 cm Courtesy Susanna Rudy
Subcutaneous	Hypoechoic Transversed by hyperechoic connective tissue	Below the epidermis and dermis, the subcutaneous layer appears as a dark layer, which represents fat and bright connective tissue	 Subcutaneous 1.9 cm Courtesy Susanna Rudy
Fascia	Hyperechoic	Deep to the subcutaneous space is the fascia, which is a thin, linear, bright-white layer	 cutaneous subcutaneous Fascia muscle Fascia muscle Courtesy Susanna Rudy
Muscle	Hypoechoic and isoechoic	Below the fascia, bright striations are organized in bundles divided by fibroadipose septa "featherlike"	 Subcutaneous fat Fascia muscle Fascia muscle 2.3 cm Courtesy Susanna Rudy
Bone	Hyperechoic Posterior acoustic shadowing	Rounded at ends and articulations Linear shafts Casts shadow below it	 Radial head bone 4.0 cm Courtesy Susanna Rudy

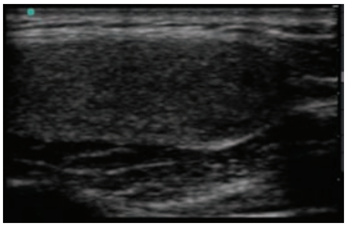
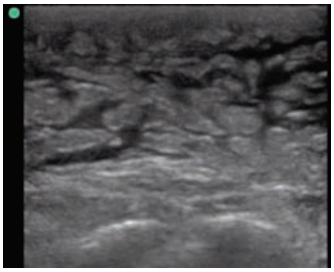
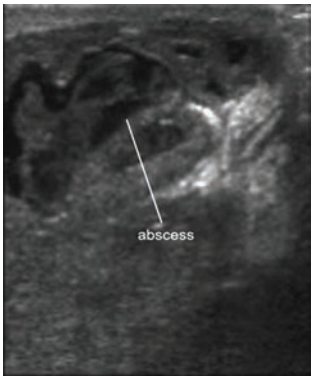
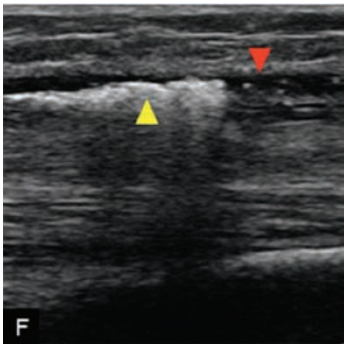
(*continued*)

TABLE 21.2 Layers of Soft Tissue With Ultrasound Imaging (*continued*)

Tissue Layer	Tissue Echogenicity	Appearance	Normal
Vessels	Anechoic	Long axis: Rectangular Short axis: Round or oval Arteries: Smaller, pulsatile, noncompressible, thick walled Veins: Thin walled, compressible	 
Nerve	Hyperechoic	Bright-white circular or oval with honeycomb appearance; embedded within soft tissue and muscle	 Courtesy Susanna Rudy
Lymph node	Well-defined echogenic center surrounded by hypoechoic rim	Irregularly round or ovoid in shape, well defined, encased	 Courtesy Susanna Rudy
Retained foreign body	Hyperechoic (displays posterior acoustic shadowing) Defined	Irregular and varied in shape but appears to be outlined (linear splinter in this image)	 With permission from https://blog.cincinnatichildrens.org/radiology/soft-tissue-foreign-bodies-foot-watch-step

(*continued*)

TABLE 21.2 Layers of Soft Tissue With Ultrasound Imaging (*continued*)

Tissue Layer	Tissue Echogenicity	Appearance	Normal
Mass/tumor	Hypoechoic Hyperechoic varies with mass	Varies (this hyperechoic homogeneous mass is an epidermal inclusion cyst)	 Courtesy Tom Costantino
Cellulitis	Increased echogenicity of skin and surrounding tissues separated by waterways of anechoic fluid collection from extravasation of fluid	Classic "cobblestone street" appearance	 Courtesy Tom Costantino
Abscess	Hypoechoic to anechoic but may appear similar to adipose	Black with irregular edges; if grey, can use probe pressure to "swirl" abscess to prove it's a liquid	 Reproduced with permission from Medscape
Necrotizing fasciitis	White hyperechoic echogenicity (*yellow arrow*) representing gas pattern in the fascial plane of forearm (*red arrow*)	Air in the subcutaneous tissue is bright white with a shadow behind it	 Mohty, K. M., Cravens, M. G., Adamas-Rappaport, W. J., Amini-Shervin, B., Irving, S. C., Stea, N., . . . Amini, R. (2017). Cadaver-based necrotizing fasciitis model for medical training. *Cureus, 9*(4), e1168. doi:10.7759/cureus.1168 Reproduced with permission from Mohty et al./Cureus. Copyright 2017.

SPECIAL CONSIDERATIONS

Ring Removal

Please see Chapter 18, Procedures for Performing Digital Anesthesia, for how to perform a transthecal digital block as this is recommended to reduce pain and minimize swelling that could complicate the procedure of ring removal.

PROCEDURE PREPARATION

Lubricant

- Gloves
- Water-based lubricant (K-Y Jelly)
- Gauze or paper towel

String Method

- Gloves
- Wide-width Penrose drain or tourniquet
- 20-in. length of string, umbilical tape, or $\frac{1}{4}$-in. packing

Ring Cutter

- Gloves
- Manual or powered ring cutter

PROCEDURE

Any injury to the upper extremity can cause swelling to the finger(s). For this reason, all rings should be removed before the swelling begins or is anticipated. In cases in which the swelling has already begun, the ring(s) can be removed using one of the three techniques listed here: lubricant, string technique, or ring cutter. Patients' rings not only have financial value but also sentimental value. For these reasons, attempts to remove the ring with lubricant and/or string should be made before resorting to a ring cutter. If possible, it is also recommended to soak the hand in ice-cold water for 1 to 2 minutes before applying a lubricant of soap, hand gel, petroleum jelly, or hand lotion. You may also try petroleum or xeroform gauze slipped under the ring to try to pull it off over the knuckle. Some metals are very strong (titanium, tungsten carbide) and will resist the ring cutter. Titanium rings can be cut off with a manual or power ring cutter; however, a diamond-coated disc or a tempered power tool steel blade is recommended. Tungsten carbide, gemstone, and ceramic rings require vice grip pliers to fracture the ring into pieces for removal.

Lubricant

- Liberally apply lubricant to the finger and rub around the ring.
- Turn the ring in a circular motion (one direction only).
- Apply traction, moving the ring off the finger past the proximal interphalyngeal joint.
- Clean the finger with gauze or paper towel.

String Method

If there is significant trauma to the finger or the patient is apprehensive and anxious, a digital block can be performed before beginning this procedure (see Chapter 11).

- Take the Penrose drain or tourniquet, and wrap it around the finger distal to proximal.
- Allow it to stay in place for a few minutes (**FIGURE 21.7**).

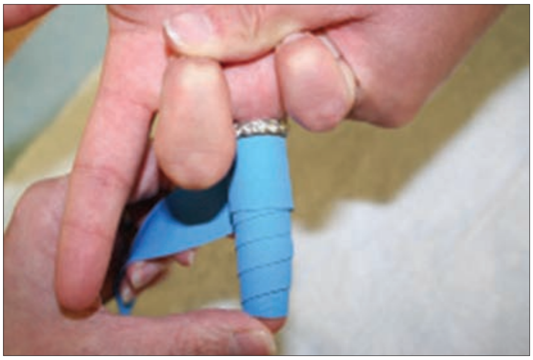


FIGURE 21.7 Penrose tourniquet application prior to utilizing the string method of ring removal.

- Remove the Penrose drain and pass the string material between the finger and ring.
- Wrap the string as close to the ring as possible distally on the finger.
- Begin to unwrap the string from the proximal end (**FIGURE 21.8**), which will begin to move the ring off the finger.

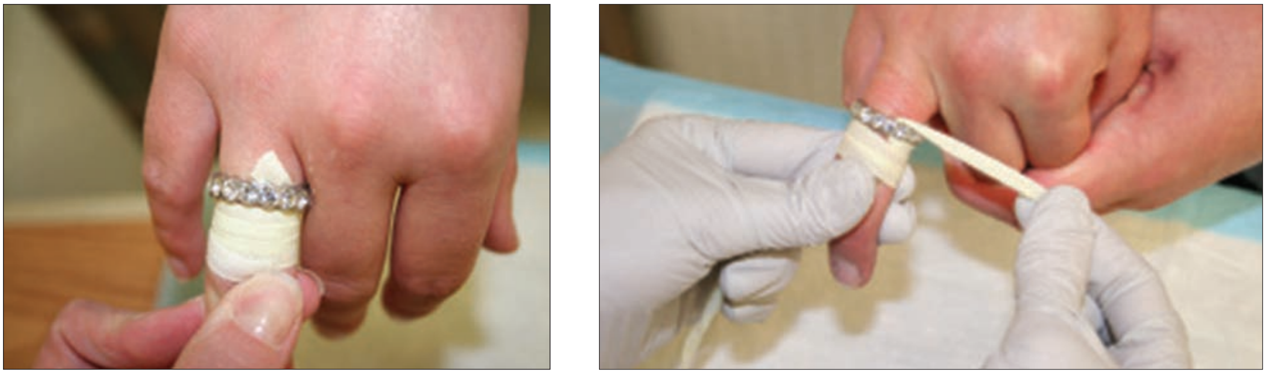


FIGURE 21.8 Ring removal via string application.

Ring Cutter

- Place the hook end of the cutter between the ring and finger (**FIGURE 21.9**).
- Allow the wheel to rest on the ring.
- Begin turning the handle if the cutter is manual or start the power on the power cutter.
- Once through the ring, attempt to spread the metal.
- If the ends of the metal are too difficult to spread, another cut may be necessary.
- Rarely needs to be utilized if the string method is properly carried out.

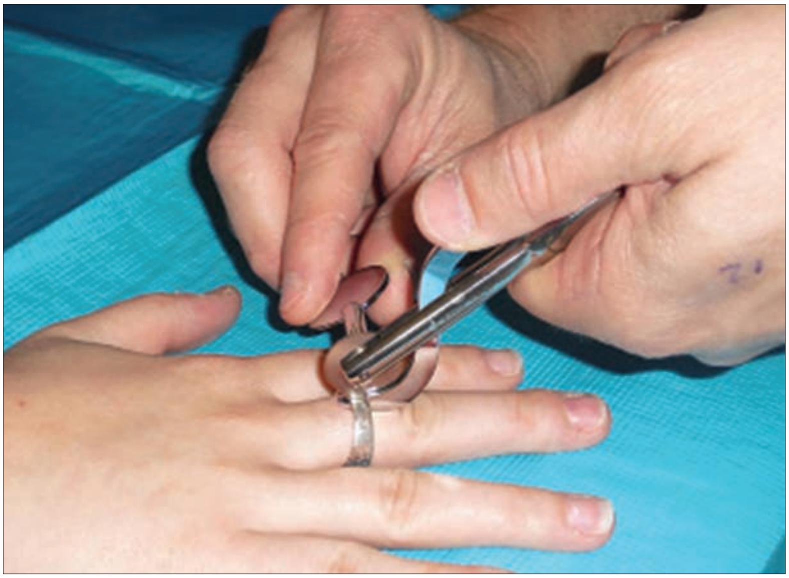


FIGURE 21.9 Ring removal via manual ring cutter.

EDUCATIONAL POINTS

- Advise the patient that the ring can be repaired by a jeweler.

COMPLICATIONS

Bacterial infections can complicate the healing process for all soft-tissue wounds. All management should be directed to minimize this risk. Some mechanisms of injury that result in soft-tissue injury are at greater risk for the development of wound infection, such as deep puncture wounds, or human or animal bites.

PEARLS

- There are three general causes for wounds that are delayed in healing or become worse: retained foreign body, infection, cancer.
- Pink or beefy-red granulation tissue is a sign of proper wound healing and represents the proliferation phase.
- Assess for history of smoking, diabetes, or arterial or peripheral vascular disease that may delay healing and require specialty management.
- Wounds with a delayed presentation but that are otherwise clean are excellent candidates for delayed primary closure.
- Ultrasound is a great tool to use to distinguish among cellulitis, abscess, and necrotizing fasciitis.
- An important function of the deepest layer of skin in the hypodermis is the fascia layer as it promotes protection from the spread of infection.
- After an injury, healed wounds never regain their original strength; approximately 1 week later, the tensile strength may be around 10% and after 1 year it can be 80%; hence, healed wounds never regain their original full tensile strength.

PEARLS

- Give reassurance and encouragement to the patient during the procedure.
- Ask whether there are any inscriptions in the ring and try to avoid that area if possible.
- Manufactured ring cutters can be either manual, electrical, or battery operated (**FIGURE 21.10**).
- It is a rare encounter in which the string method does not remove a ring.

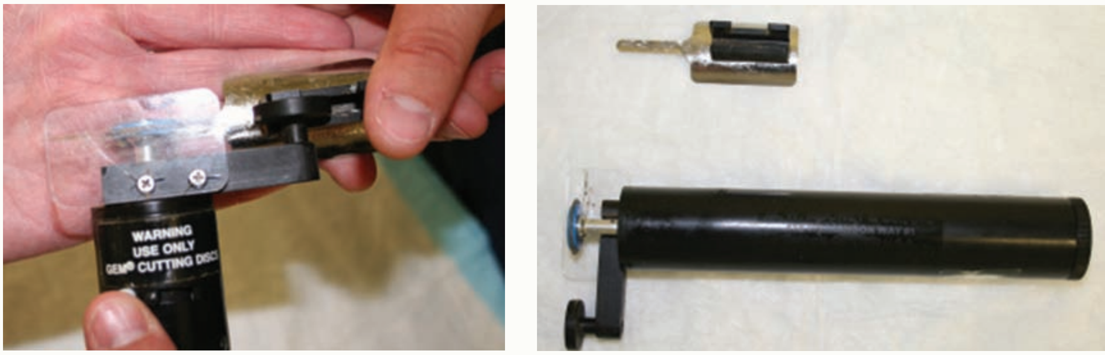


FIGURE 21.10 Ring removal via automatic ring cutter.

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CHAPTER

22

Procedures for Managing Puncture Wounds

Jane Holston and Susanna Rudy

BACKGROUND

Puncture wounds are commonly seen in ED and urgent care settings and can be caused by a wide variety of mechanisms. Injuries caused by punctures to the skin can range from minor localized pain to life-threatening infections. Deep puncture wounds not only damage tissue, but can penetrate bones, tendons, and joint spaces, and inoculate bacteria, debris, and other foreign bodies into the wound. Puncture wounds often occur when a person steps on a sharp object that is either contaminated or becomes contaminated as it penetrates through materials such as shoes and/or other clothing. A puncture through the sole of a rubber athletic shoe, for example, can deposit *Pseudomonas* deep into the tissues, which then closes up and traps bacteria and other contaminates inside the wound. For this reason, puncture wounds must be thoroughly assessed and appropriately treated, beginning with a thorough history and physical that specifically focuses on how, where, and when the injury occurred.

PATIENT PRESENTATION

- Pain and tenderness (may be out of proportion to outer appearance of wound)
- Swelling
- Bleeding
- Erythema
- Puncture site (may be very obvious or barely visible)
- Cellulitis and/or drainage may be present

TREATMENT

- Ideally, the patient should seek treatment within 6 hours, but the sooner the treatment is initiated, the better the outcome.
- Tetanus prophylaxis must be given unless the patient has had the vaccine within 5 years. If patient is unsure, always opt on the side of caution and give it.
- The extent of imaging depends on the extent of the injury. X-rays should be obtained on most all puncture wounds to assess for radiopaque foreign bodies, fractures, and other injuries (**FIGURE 22.1**). Ultrasound, CT, and MRI can be used to assess for nonradiopaque foreign bodies and infectious processes. **FIGURE 22.2** demonstrates a foreign body visualized with ultrasound and CT scan. Ultrasound may not detect small foreign bodies, so CT should be considered if suspected. MRI should be used when osteomyelitis, septic arthritis, or a deep-space abscess is suspected, but be careful to ensure that no metallic foreign bodies are present (**FIGURE 22.3**).

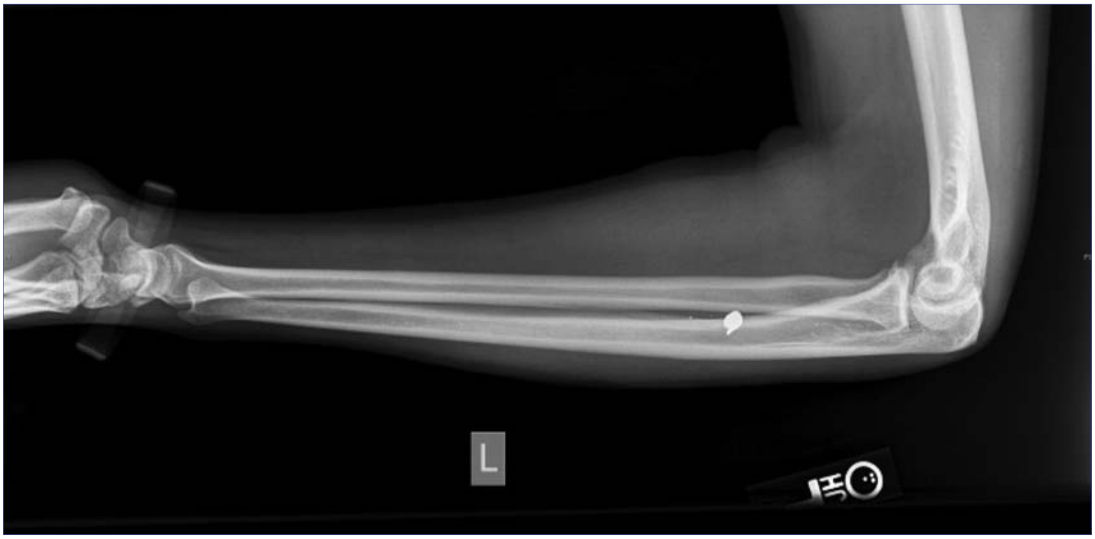

FIGURE 22.1 X-ray demonstrates a radiopaque foreign body.

Source: Reproduced with permission from Bannerman, C. C. (2019). Wound foreign body removal. In E. D. Schraga (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/1508207-overview. Courtesy of Robert Mittendorff.

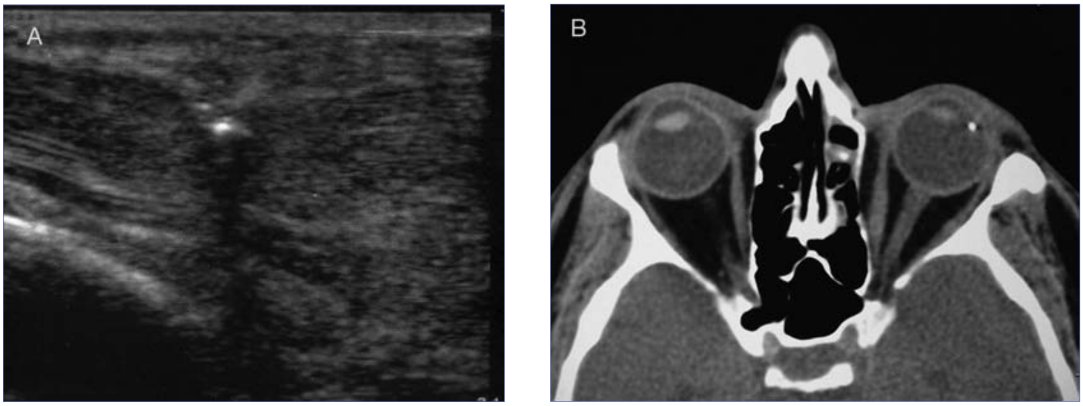

FIGURE 22.2 Foreign body visualized with (A) ultrasound and (B) CT scan.

Sources: Reproduced with permission from (a) Bannerman, C. C. (2019). Wound foreign body removal. In E. D. Schraga (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/1508207-overview; (b) Kuhn, F. (2017). Intraocular foreign body (IOFB). In I. I. Dersu (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/1230338-overview. Courtesy of Robert Mittendorff.

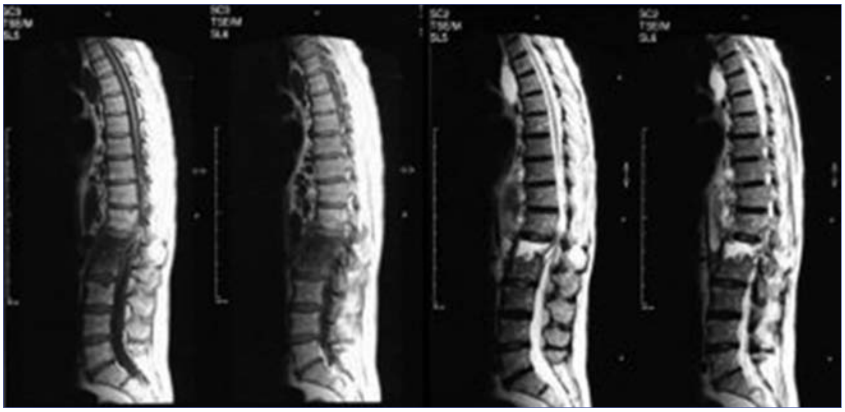

FIGURE 22.3 MRI demonstrates osteomyelitis of the spine.

Source: Reproduced with permission from Khan, A. N. (2017). Chronic osteomyelitis imaging. In F. S. Chew (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/393345-overview

- Management of a puncture wound can range from simple cleansing of the wound to surgical treatment and largely depends on the history of the injury, the physical exam, and the health of the patient. It is important to obtain as much information as possible about the mechanism of injury such as the type of object, whether it pierced through clothing or footwear, whether it occurred in fresh water (such as a lake or stream) or salt water, and approximate depth of the puncture. X-rays should be obtained on all puncture wounds if there is any chance that a foreign body may be present. If there is any doubt, always assume that a foreign body is present.
- Contaminated puncture wounds should be opened, inspected for foreign bodies and debris, thoroughly cleaned, and left open to allow for drainage. Puncture wounds should never be sutured closed.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

For patients who present with high-pressure injection (HPI) injuries from equipment, such as grease or paint guns to the hands or fingers, **digital nerve blocks are contraindicated** due to the potential to increase pressure in the compartments of the injured hand or fingers (Lemus & Darnsteadt, 2017). These injuries may look benign initially; however, due to the potential depth of penetration, surgical debridement should take place immediately to reduce the risk of compartment syndrome. Management includes opioids for pain control, antibiotic and tetanus prophylaxis, radiographs for initial evaluation, and immediate consult with a hand surgeon.

SPECIAL CONSIDERATIONS

Wound Consideration

- Depth of the wound
- Time and source of the injury (> 24 hours)
- Contamination of the wound
- Underlying structures are involved (e.g., joint, bone, tendon).

Patient Consideration

- Immunosuppression or immunocompromised
- Circulatory insufficiency
- Underlying medical conditions (diabetes)
- Anticoagulant therapy

PROCEDURE PREPARATION

- Absorbent pads
- Basin
- Gauze
- Sterile normal saline
- 1% povidone-iodine solution (optional)
- 20- to 60-mL syringe
- Splash guard or 16- to 18-gauge angiocatheter

If incising the wound to inspect and remove foreign body or contamination:

- 1% lidocaine (may add 8.4% sodium bicarbonate 1 mL/1% lidocaine 9 mL [1:9 ratio] to minimize pain with administration)
- 10-mL syringe and needles to draw and administer anesthetic
- No. 11 or No. 15 scalpel
- Forceps

PROCEDURE

Inspection

Closely inspect the area for signs of infection such as erythema, foul-smelling drainage, induration, fluctuance, or warmth. Check neurovascular status distal to the injury and assess for tendon damage if applicable.

Cleansing

For relatively clean, superficial wounds with no evidence of foreign body or other contamination, rinse with cool tap water or normal saline and clean using gauze soaked in sterile normal saline or 1% povidone-iodine solution. Irrigate with sterile normal saline using a syringe and angiocatheter for low-pressure irrigation (or you may use a syringe and a splash guard if preferred). Apply antibiotic ointment and cover with a sterile dressing.

Incision and Debridement

- Wounds that are deep, contaminated, contain foreign bodies, show signs of infection, or for which treatment has been delayed often require incision and debridement.
- Cleanse the area as described earlier.
- Administer local anesthesia (see Chapter 16, Anesthetic Agents and Procedures for Local and Field Infiltration).
- Slightly enlarge the puncture wound using a scalpel.
- Debride the area of debris, nonviable tissue, and foreign bodies.
- Forceps can be used to gently open the wound for better visualization, but probing the wound can further damage tissue and push contaminates and foreign bodies further into the wound.
- Gently irrigate using a syringe with an angiocatheter or splash guard attached.
- Apply a topical antibiotic and dressing, leaving the wound open to allow for drainage.

ULTRASOUND GUIDANCE

Ultrasound guidance may be useful in visualizing foreign bodies. It can also help to locate and avoid damaging any vascular or other underlying structures when incising a puncture wound.

POSTPROCEDURE CONSIDERATIONS

The decision as to whether or not to prescribe antibiotics depends on the source of the injury, its location on the body, and the health of the patient. For clean superficial wounds that are cleaned and inspected within 24 hours, antibiotics may not be needed. For wounds that occurred more than 24 hours ago, are contaminated, and/or show signs of infection, coverage for *Staphylococcus* and *Streptococcus* should be initiated and could include cephalexin or amoxicillin–clavulanic acid. If there is suspicion of possible inoculation with *Pseudomonas* (injury occurred through the rubber sole of an athletic shoe), a fluoroquinolone, such as ciprofloxacin, should be used. If the injury occurred in fresh water, coverage for *Aeromonas* could include a fluoroquinolone for adults or trimethoprim–sulfamethoxazole for pediatric patients. If the puncture occurred in salt water, coverage for *Vibrio vulnificus* could include doxycycline or levofloxacin.

Pain medication should be prescribed based on the patient's level of pain. Acetaminophen and nonsteroidal anti-inflammatory drugs (NSAIDs) are usually sufficient and well tolerated by the patient. Crutches can be used for a few days to reduce the discomfort of a puncture wound to the foot.

Advise patient to keep the wound elevated as much as possible to reduce pain and swelling, clean with a gentle cleanser once per day, apply antibiotic ointment, and use a clean dressing.

The patient should be instructed to follow up in 24 to 48 hours to assess for signs of infection. Close follow-up should continue for as long as indicated depending on the risk factors and extent of the injury. Patient should receive strict return precautions for worsening pain, erythema, swelling, warmth, and foul-smelling or colored drainage, and to watch for signs of systemic infection such as fever, chills, and body aches.

Patients with signs of severe infection should be admitted to the hospital and proper consults obtained such as surgery, podiatry, or infectious disease.

EDUCATIONAL POINTS

- Infections to bones or joints may occur weeks to months after the outer wound has healed.
- *Staphylococcus* and *Streptococcus* are the infections most commonly seen from puncture wounds.
- *Pseudomonas* is a major cause of osteomyelitis when the puncture is through a rubber-soled athletic shoe (think dark and moist), which serves as a breeding ground for bacteria. Follow-up with a foot specialist should be arranged in 3 to 4 weeks in these cases to detect early signs of osteomyelitis. Antibiotics effective against *Pseudomonas* should be prescribed in this circumstance.
- No evidence has been shown to support any benefit in giving a single dose of parenteral antibiotics prior to starting oral (PO) antibiotics.
- Attempting to remove a deeply embedded foreign body in the ED may not be feasible; therefore, obtaining a surgical consult is recommended.
- Diabetic patients often have peripheral neuropathy, so puncture wounds to the feet may go undetected due to decreased sensation. In addition, these patients are more prone to infection, putting them at a much higher risk of serious infection which could lead to amputation of the extremity or even death.
- Punctures from needlesticks are common in healthcare workers and treatment should follow facility protocols or current Centers for Disease Control and Prevention (CDC) guidelines.

COMPLICATIONS

- Abscess (localized or deep-space abscess)
- Cellulitis
- Retained foreign body
- Septic arthritis
- Osteomyelitis

HIGH-PRESSURE INJURIES

BACKGROUND

High-pressure injuries (HPI) result from injected force pressures between 2,000 and 10,000 pounds per square inch (psi) at velocities up to 400 miles per hour. They are extremely serious, requiring early surgical management for best outcomes. These injuries are associated with a high incidence of morbidity, and an amputation rate up to 40%, if undiagnosed on initial exam. Risk of amputation increases with higher pressures, a delay of treatment greater than 6 hours, or exposure to organic solvents. Pressures greater than 7,000 psi are associated with a 100% rate of amputation.

HPI injuries are rare and most commonly occur in automotive or industry-related accidents. Injuries can occur when handling spray, grease, concrete or paint guns, diesel, or plastic or hydraulic fuel injectors. Potential organic solvents and cytotoxic liquid substances injected include, but are not limited to, paint (latex, oil), gasoline, grease, jet fuel, hydraulic fuel, water, wax, paint thinner, cement, plastic, and oils. Oil-based organic substances are associated with poorer outcomes than water-based materials. Any barrier material (gloves, clothing) can also be injected into the area as pressure passes through them.

A thorough history and physical assessment is imperative to properly diagnose presentations of HPI injuries. It is important to note hand dominance. Most occur in the nondominant index finger. Extent of injury can be underestimated due to the initial appearance of a small puncture wound, slight discoloration, or the wound itself may be obscured by the expressed injectate, making it difficult to fully assess. There may not be any obvious evidence of a wound other than a hint of swelling or discoloration. In some instances, a small amount of injectate may be able to be expressed from the wound. High-pressure jets can penetrate soft tissues without direct contact with the skin. Performing a neurovascular exam is key to identifying early compartment syndrome. Not all injections cause immediate pain, which can delay presentation for those working when injury occurred. Direct involvement of the radial or ulnar nerve is rare. Initial evaluation of overall function of the hand and palmar tendon sheaths should be performed and documented for trending during management and evaluation. Delayed presentation often occurs related to insidious swelling and debilitating pain proportionate to type and amount of injectate. Pallor and hypoesthesia are further warning indicators of impending compartment syndrome. Preventative measures involve educating the patient on the diagnoses and all aspects of care and potential outcomes.

PATHOPHYSIOLOGY

There are three phases to HPI injuries: direct tissue insult, inflammation, and inoculation of potentially pathogenic microbiota resulting in secondary infection. All high-pressure liquid injections cause substantial superficial and deep, extensive soft tissue damage. They can tear ligaments and tendons, and cause osseous lesions. Once the force is applied, high-pressure injectate enters the subcutaneous space and follows the path of least resistance along the planes of the neurovascular bundles. Direct insult to neurovascular structures results in occlusion leading to edema, ischemia, necrosis, and an acute development of compartment syndrome with impaired neurovascular function. The second phase is hallmarked by inflammation. The degree of inflammation is related to the cytotoxicity and amount of the substance injected. Organic substances potentiate a severe inflammatory response. Oil-based products are more inflammatory than water-based solvents. Air and water have the least inflammatory effect and are passively reabsorbed over time. The third phase anticipates secondary infection through direct injection of bacteria into the soft tissues. Necrotic tissue provides an excellent medium to support bacterial growth, wound cultures isolate polymicrobials, but a majority of the organisms are Gram-negative bacteria requiring antibiotic therapy.

MANAGEMENT

Early diagnosis and surgical consultation with a specialist (plastics or hand surgery) is required. Initial irrigation of visible wounds should be done with normal saline 0.9% through gravity flow; avoid pulse or high-pressure irrigation of the wound. Aggressive surgical management is time sensitive. Wound exploration, decompression, evaluation of tendon sheaths, copious irrigation and debridement of injectate, and necrotic tissue are the primary management strategies used to preserve tissue and restore function. Washouts and debridement may be planned in stages to optimize soft tissue recovery to place flap or skin grafts. Extension of infiltrate into the flexor tendon sheath of the palm may require extension of the dissection. Consider transfer to a facility with higher level of care resources following initial management.

Imaging is mandatory and may be the initial diagnostic modality of choice to evaluate the extent of injury, including the presence of a fracture or retained foreign body. Injectates are not radiopaque, lending difficulty to differentiating the location of injectate or extent of tissue damage. Radiographs are beneficial in identifying soft tissue air and debris, which may extend far beyond the entrance wound (**FIGURE 22.4**). The use of bedside point-of-care ultrasound (POCUS) with a musculoskeletal exam type, high-frequency probe (5–12 MHz) can provide immediate imaging surveillance of the superficial structures and identify abnormalities to soft tissue as well as be able to assess vascular compromise with color or Doppler imaging techniques. Abnormal findings should be followed up with a complete exam or more extensive imaging as required. Other initial management strategies include avoiding application of ice, which can impair perfusion; elevate the affected limb; or initiate analgesic pain management and empiric antibiotics and tetanus prophylaxis. The use of steroids has not been demonstrated to be of benefit but is also not harmful. Digital blocks should be avoided to prevent vasospasm and additional swelling from local anesthetic. Ongoing assessment involves evaluation for development of compartment syndrome.

Complications from delayed management of HPI injuries can be life-threatening or permanently disabling. Neurovascular function can be lost or damaged, and hypersensitivities, permanent contractures, deformities, motor dysfunction, paralysis, chronic pain, hypoesthesia, parasthesia, infections, osteomyelitis, or loss of limb are all real potential outcomes with this type of injury.

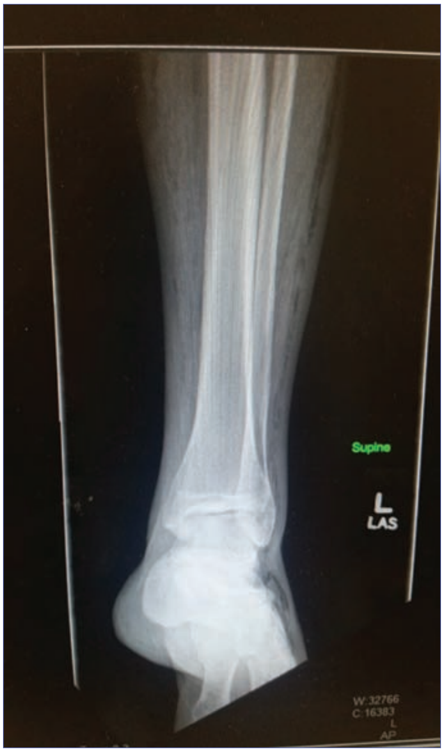

FIGURE 22.4 Air forced into the soft tissue demonstrated on the radiograph as black/dark gray in a linear manner from the entrance at the proximal lower leg down to the foot. Air visualized bilaterally near the entrance wound.

Source: Courtesy of Theresa Campo.

PEARLS

- When x-raying to rule out a foreign body, remember this: If it floats, it likely will not be seen on x-ray (e.g., wood, thorns, and grass). If it sinks, such as metal or glass, it will likely show up on an x-ray.
- Consider all puncture wounds contaminated.
- Assume all puncture wounds contain foreign bodies.
- Puncture wounds are like icebergs; what is seen on the surface may be just a small indication of what may be going on underneath.

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CHAPTER
23

Procedures for Removing a Soft-Tissue Foreign Body

Kelley Toffoli and Theresa M. Campo

BACKGROUND

Soft-tissue foreign bodies (FBs) are more common in children and occur most frequently in the extremities. The most commonly seen FBs are glass, wood, and metal. Geographical region may influence the type and frequency of FBs seen (Agarwal, 2018). For example, areas along the coast may see more fishhooks, wood splinters, and fish spines than the Midwest.

Any wound or injury causing disruption of the integument should be considered for a possible retained FB. It is essential to evaluate fresh wounds meticulously in a bloodless field for a retained FB. When a FB is identified, several considerations must be made. The clinician must determine the urgency of FB removal. Some FBs require immediate removal. Some FBs are complicated or deeply embedded; thus, removal may be delayed. FBs in the soft tissue can be composed of various materials. Commonly, wood, thorns, ticks, and other vegetative materials can cause a rapid inflammatory response in soft tissue, sometimes infective. Inorganic materials, such as metal, glass, plastic, and rubber, usually do not result in such a severe inflammatory reaction. Bullet or glass fragments by themselves rarely produce wound infection.

FB location should be carefully considered. For example, FBs of the head and neck can have complications related to hemorrhage and can impact critical areas necessary for vital function. In addition, head and neck FBs can affect the physical and mental well-being of patients (Yefeng, Hongbing, Linzhong, & Hua, 2018). It is recommended that head and neck FBs be removed within 24 hours in order to reduce complications related to inflammation, bleeding, and infection.

Obtaining a thorough history and physical examination are essential. Assessment of patient's perception of possible retained FB can be helpful. Stone and Scordino (2019) found that a patient's negative predictive perception was 89%, whereas positive predictive value of a retained soft-tissue FB was 31%. Studies have shown that more than one third of soft-tissue FBs are missed on initial examination (Stone & Scordino, 2019). If the patient states that he or she feels that an FB is present, you should maintain a high index of suspicion. A missed FB can lead to infections, including osteomyelitis, deep-space abscess, tissue necrosis, and granuloma formation, not to mention open a clinician to malpractice claims.

Obtaining essential information related to the location, mechanism, timing, composition, occupation, tetanus status, history of diabetes or immunosuppression, and hand dominance (if upper extremity is involved) are key features of the history when evaluating soft-tissue FBs. Assessment of contamination and surrounding structural function (nerve, tendon, muscle, etc.) are imperative to ensure that the clinician properly identifies and provides proper treatment to the patient.

PATIENT PRESENTATION

- Puncture wound often painful with or without visible FB
- Bleeding
- Discoloration (erythema, bruising)
- Swelling
- Nonhealing wound with or without granuloma formation
- Signs of infection such as cellulitis or abscess formation

Imaging

Blind exploration is sometimes hazardous for patients, especially when it is in proximity to an associated vessel, nerve, or an overlying tendon (Tantray et al., 2018). Diagnostic imaging can be very useful with regard to identification and retrieval of soft-tissue FBs. Multiple studies have compared the different types of imaging to assist with identification of potential retained soft-tissue FB.

Ultrasound (US) is quickly becoming the gold standard for identifying embedded FBs. US has been found to be the only imaging modality capable of detecting plastic, organic, and glass materials (Huttin et al., 2018). US can be readily available and is considered to be a cost-effective diagnostic modality. US can effectively determine the presence, size, and depth of an FB as well as proximity of FB to an adjoining nerve, vessel, or tendon. Use of US has been found to minimize false-negative surgical explorations and prevent damage to adjoining structures (Tantray et al., 2018). US can be used for guided removal of elusive organic FBs and is mainstream for detecting radiolucent FBs (>90% sensitivity), such as wood and rubber.

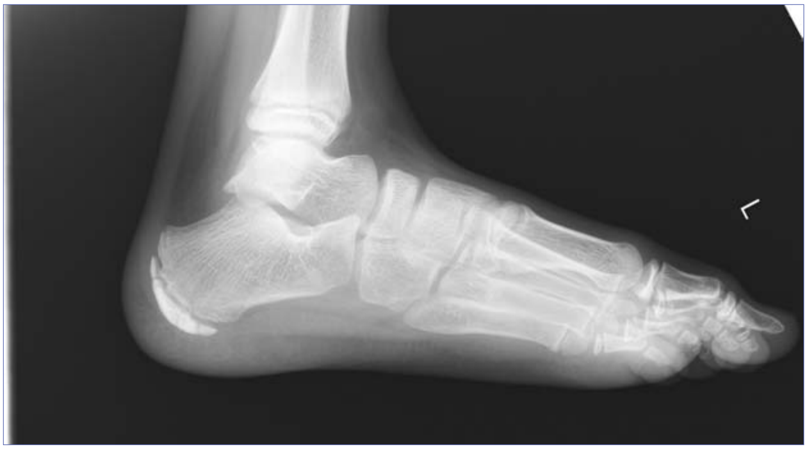


FIGURE 23.1 Plain x-ray of foot with suspected wood foreign body.

Plain-film radiographs (x-ray) are a cost-effective and commonly used diagnostic adjunct to identify radiopaque FBs. FBs, such as wood, thorns, ticks, plastic, rubber, and other vegetative materials, are generally referred to as *radiolucent*, or difficult to identify with plain-film radiographs. Metal and nearly all types of glass larger than 5 mm are radiopaque or can be identified on radiographs. Multiple x-ray views can help in localization. CT scan can be used to visualize FBs with a higher sensitivity than plain radiographs. The overall sensitivity is 95%, specifically, 100% for metal; 75% for glass; and 7% for wood (**FIGURE 23.1**).

TREATMENT

Treatment is largely based on the patient's presentation. The time to presentation, location, depth, size, FB composition, risk of neurovascular injury, risk of infection, cosmetic outcome, functional impairment, acute and potential for chronic pain, and patient's desire to have FB removed should all be considered when a patient presents with a potential soft-tissue FB (Agarwal, 2018).

Various methods are acceptable for soft-tissue FB removal. FBs can be irrigated away, excised, evacuated with instruments, or debrided from a wound. There are multiple methods used for fishhook removal, which are also discussed in this chapter.

Superficial horizontal FBs sit in the dermal and epidermal layer of the skin along the horizontal axis. If the FB is visible and palpable, it can be removed by excision. If the FB is perpendicular to the skin surface in a vertical orientation with only a very small surface, if any, exposed, it can be difficult to remove. The object may become displaced when an incision is made, making removal more complicated and causing additional trauma to the tissue. Incision and coring may be necessary to remove this type of FB. A subungual FB is located beneath the nail plate. Cutting the nail in a "V" shape and removing the splinter is the most common method of removal. Performing a digital block and elevating the nail for removal is another option. Elusive FBs may require referral or guided removal with either fluoroscopy or US.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Deep, elusive FBs
- Inability to obtain and maintain hemostasis for complete evaluation and removal
- Poor cosmetic outcome
- Intra-articular FB
- FB embedded in bone

SPECIAL CONSIDERATIONS

- Diabetics
- Immunocompromised patients
- Anticoagulant therapy

PROCEDURE PREPARATION

Foreign Body

SUPERFICIAL HORIZONTAL, VERTICAL, AND SUBUNGUAL PRESENTATION

- Skin cleanser
- Absorbent pad
- Gloves
- Topical or injectable anesthetic
- Small, superficial FBs, and/or calloused skin may not require any anesthetic
- No. 11 or No. 15 scalpel
- Splinter or fine forceps
- Small scissors
- Hemostat
- Normal saline for irrigation
- 35- to 65-mL syringe (for irrigation)
- 16- to 18-gauge angiocath or splashguard
- Skin cleanser scrub
- Dressing material
- Antibiotic ointment

ELUSIVE FB

Removal should not be attempted if the object cannot be visualized. Referral is recommended for these patients.

Fishhook

RETROGRADE TECHNIQUE

- Gloves
- Normal saline for irrigation
- Skin cleanser

STRING YANK

- Gloves
- Normal saline for irrigation
- Skin cleanser
- String (thick suture material or umbilical tape)

NEEDLE COVER

- Gloves
- Normal saline for irrigation
- Skin cleanser
- Injectable anesthetic
- Large-gauge needle (18 gauge or larger)

ADVANCE AND CUT

- Gloves
- Normal saline for irrigation
- Skin cleanser
- Injectable anesthetic
- Needle driver, hemostat, or pliers

PROCEDURE

Foreign Body

SUPERFICIAL HORIZONTAL PRESENTATION

- Cleanse the skin.
- Use topical or local anesthetic.
- The type of anesthetic is determined by size, location, and depth of the FB and patient tolerance.
- Make an incision along the FB. Incise the entire length to ensure full removal.
- Apply gentle pressure to one end of the FB while lifting the opposite side (**FIGURE 23.2**).
- Grab the FB with forceps.
- Irrigate with a copious amount of normal saline.
- Scrub the area to loosen debris and contamination, if necessary.
- Apply dry sterile dressing with Vaseline or antibiotic ointment.

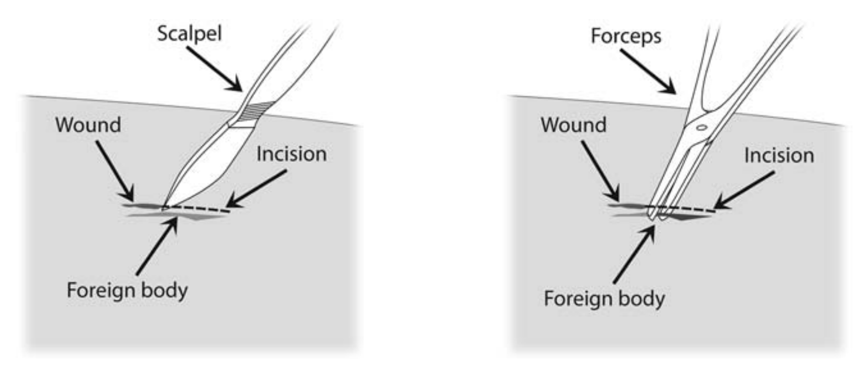
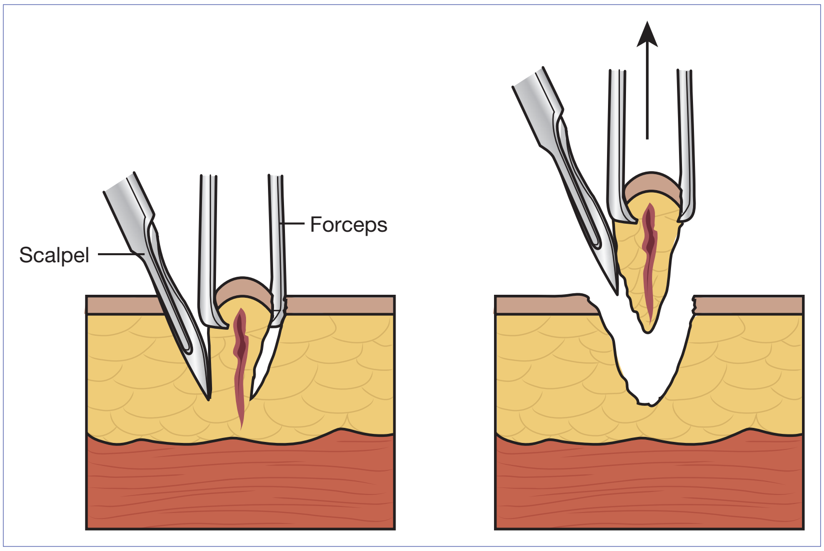


FIGURE 23.2 Illustration depicting superficial horizontal foreign-body removal technique.

VERTICAL PRESENTATION

- Cleanse the skin.
- Perform local anesthesia.
- Make an incision over the FB.
- Secure the FB, if possible, with the forceps.
- Incise around the FB (coring).
- Remove the entire section.
- Irrigate with a copious amount of normal saline.
- Scrub the area to loosen debris and contamination, if necessary.
- Apply dry sterile dressing with antibiotic ointment (**FIGURE 23.3**).

FIGURE 23.3 Illustration depicting vertical foreign-body removal technique.



SUBUNGUAL PRESENTATION

- Cleanse the area.
- Perform a digital block.
- With either the scalpel or small scissors cut a “V” shape from the distal nail.
- The point of the “V” should go to the proximal end of the FB.
- Be careful not to cut or cause undue trauma to the nail bed.
- Remove the piece of nail with either the forceps or hemostat.
- Grasp the FB with the splinter forceps and remove by gently pulling.
- Irrigate with a copious amount of normal saline.
- Scrub the area to loosen debris and contamination, if necessary.
- Apply dry sterile dressing with antibiotic ointment (**FIGURE 23.4**).

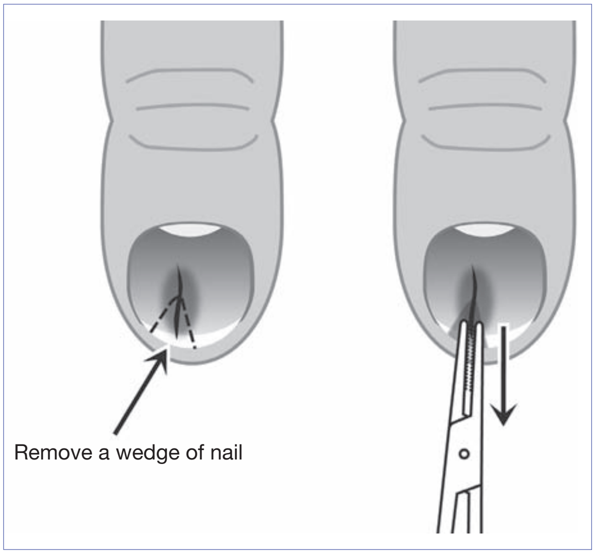


FIGURE 23.4 Illustration depicting removal of a subungual foreign body.

Fishhook

- Fishhook removal can be a challenge to the clinician. There are numerous types of hooks and the patient may not be astute as to the type and size of the hook. Always ask the patient about the type of hook (no barb, barbed with single or multiple barbs, or treble; **FIGURE 23.5**). Key to successful removal of fishhooks is disengaging the barb from the tissue. The technique for removal depends on the depth and type of hook that is embedded.

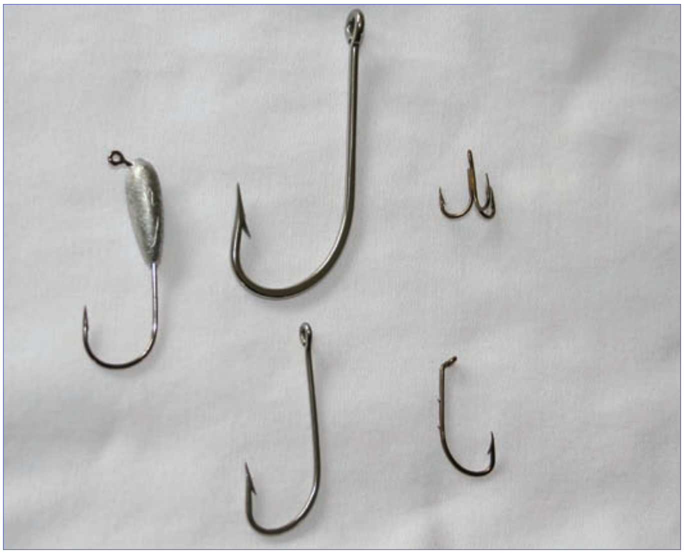


FIGURE 23.5 Photograph showing several types of fishhooks.

RETROGRADE TECHNIQUE

This technique should be used for hooks that are barbless and superficially positioned. It can be attempted if the hook is small and barbed (**FIGURE 23.6**).

- Apply downward pressure to the base or shank of the hook.
- Gently rotate to disengage the barb.
- Begin to back the hook out.
- If any resistance is felt, stop the procedure and use another method.
- Irrigate with a copious amount of normal saline.
- Scrub the area to loosen debris and contamination, if necessary.
- Apply dry sterile dressing with antibiotic ointment.

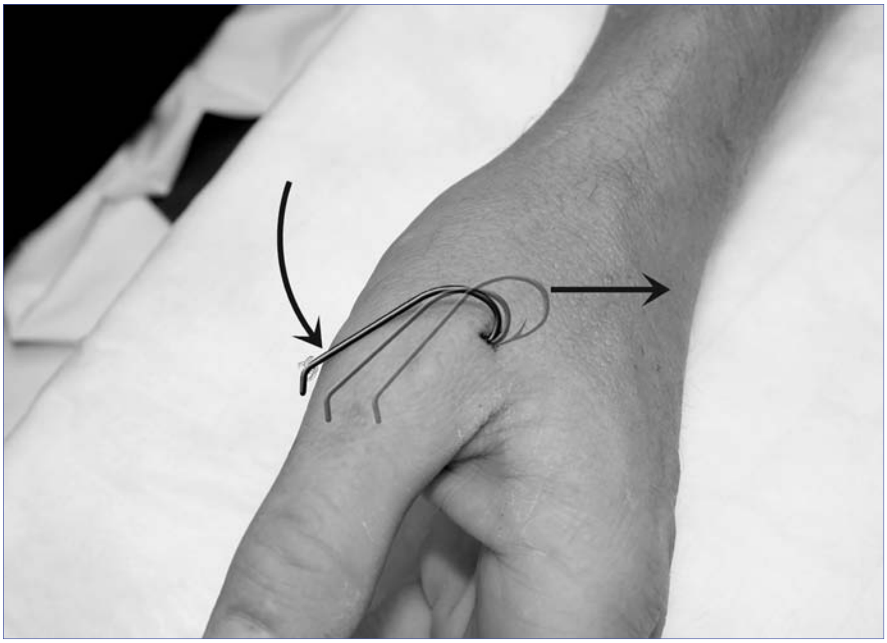


FIGURE 23.6 Photograph demonstrating retrograde fishhook removal technique.

STRING YANK

This technique is best for small- to medium-sized fishhooks. Successful removal is best performed on fixed body parts (**FIGURE 23.7**).

- Cleanse the area.
- Topical or local anesthetic may be needed based on the patient's tolerance.
- Wrap the string around the center of the fishhook.
- Hold the ends tight.
- Rest the affected area on the table.
- Apply downward pressure to the base or shank of the hook.
- Push the distal end of the hook (the eye) against the skin while pulling on the string.
- Irrigate with a copious amount of normal saline.
- Scrub the area to loosen debris and contamination, if necessary.
- Apply dry sterile dressing with antibiotic ointment.

NEEDLE COVER

This technique can be used for any size fishhook with a single barb (**FIGURE 23.8**).

- Cleanse the area.
- Perform local anesthesia through the wound to reduce trauma to the area.
- Line up the large-gauge needle with the bevel facing the hook.
- Advance the needle through the opening and follow the hook.
- Push the hook forward and down slightly.
- You may have to slightly rotate the fishhook to help disengage the tissue.
- Then begin to pull the hook out with the bevel of the needle over the barb.
- Irrigate with a copious amount of normal saline.
- Scrub the area to loosen debris and contamination, if necessary.
- Apply dry sterile dressing with antibiotic ointment.

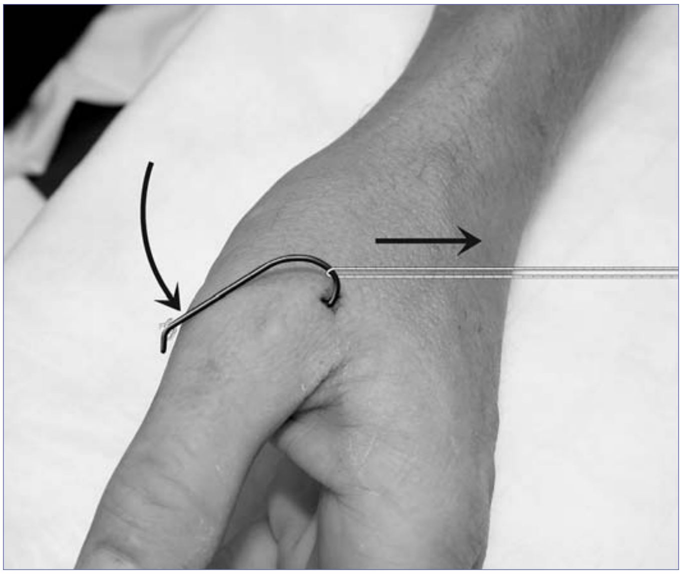


FIGURE 23.7 Photograph demonstrating string-yank fishhook removal technique.

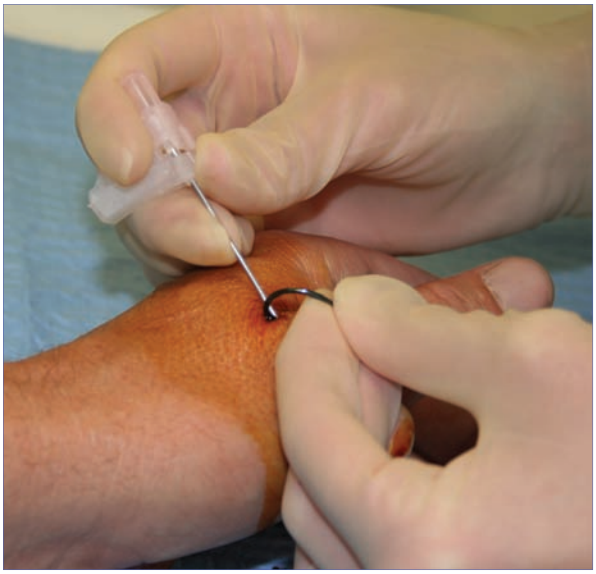


FIGURE 23.8 Photograph showing needle-cover fishhook removal technique.

ADVANCE AND CUT

This technique can be used for any size hook with a single or multiple barbs (**FIGURE 23.9**).

Single Barb

- Cleanse the area.
- Perform local anesthetic.
- Push the point of the fishhook through the skin where it was tenting.
- If unable to push through the skin, make a small incision.
- Grab and secure the point of the hook with a needle driver or hemostat.
- Cut the point of the hook below the barb with wire cutters or other available cutting tools.
- Grasp the proximal end of the hook (the eye) and back the hook out.
- Irrigate with a copious amount of normal saline.
- Scrub the area to loosen debris and contamination, if necessary.
- Apply dry sterile dressing with antibiotic ointment.

Multiple Barbs

- Follow the aforementioned procedure, but cut the eye of the hook and pull the hook by the point (barb end).

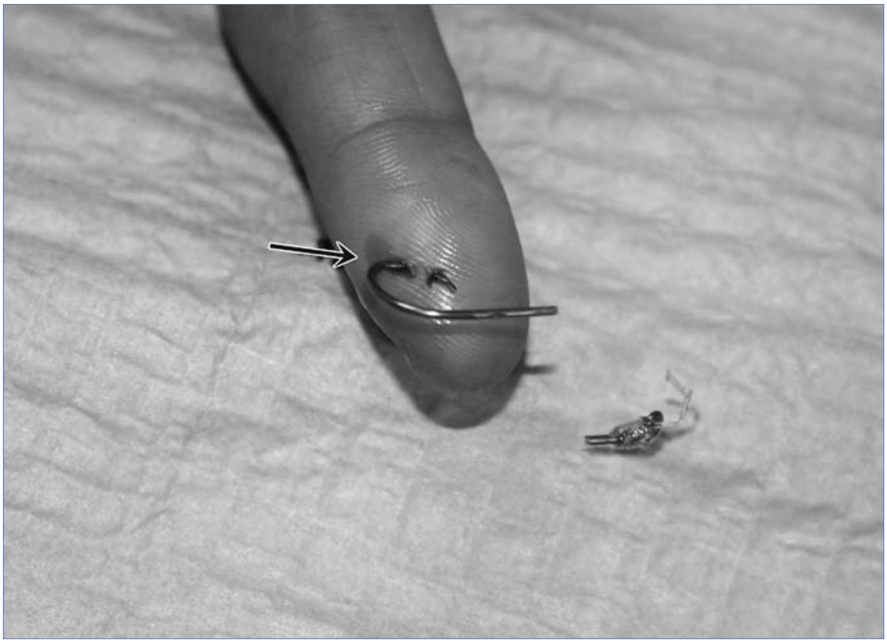


FIGURE 23.9 Photograph showing advance-and-cut fishhook removal technique.

Tick Removal

Ticks embed themselves in order to feed on a host. There are numerous types of ticks; they can carry bacteria, viruses, toxins, spirochetes, Rickettsiae, and protozoa. Lyme disease, ehrlichiosis, Rocky Mountain spotted fever, and other illnesses can be caused by a prolonged tick bite, usually >36 hours. Therefore, ticks that have been attached for more than 36 hours present a greater risk for spirochete transmission (Bush & Vazquez-Pertejo, 2018). For this reason, health authorities worldwide, including the World Health Organization and the Centers for Disease Control and Prevention, advise that ticks should be removed as soon as possible because of the concerns regarding infectious disease transmission (Taylor, Ratchford, van Nunen, & Burns, 2019).

Over-the-counter tick-removal devices are available (TRIX, Tick key, Sawyer tick pliers, etc.). Do not apply any products to the tick to attempt to kill or "stun" the tick. This may cause the tick to regurgitate and spread infection. The most effective method of tick removal is to use fine-tipped forceps to grip the tick by the mouthparts, lifting them away from the skin using firm and even pressure (Taylor et al., 2019). It is most important to avoid squeezing the tick's body and to avoid separating mouthparts anchored to affected skin. Squeezing a tick by the body may cause stomach contents and saliva, toxins, allergens, and pathogens to be ejected into the bite site (Taylor et al., 2019).

Some geographic areas in the United States have greater incidence of Lyme disease. Approximately 95% of diagnosed cases are concentrated in the Northeastern, Mid-Atlantic, and North Central United States. In endemic areas, the annual incidence of Lyme disease is between 10 and 100 cases per 100,000 persons. A single 200-mg oral dose of doxycycline has been found to prevent Lyme disease, and should be offered within 72 hours (Bush & Vazquez-Pertejo, 2018). Special consideration should be made for those individuals living in and traveling from endemic regions.

- Wear gloves. Ticks can pass infection with direct contact, not just bites.
- With fine-tipped forceps (or fine-tipped hemostat), grasp the tick as close to the skin as possible (**FIGURE 23.10**).
- Apply even traction while pulling upward until the tick is removed.
- Do not twist, crush, or jerk when removing.
- Inspect for and remove any retained mouth or body parts.
- Cleanse the area with soap and water.

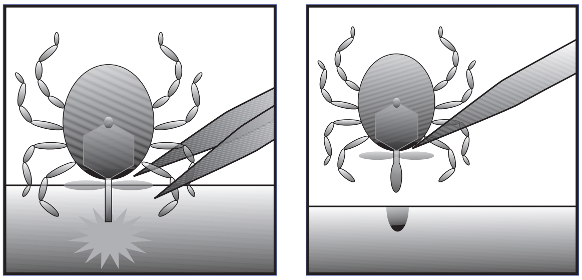


FIGURE 23.10 Illustration depicting removal of tick with forceps.

Source: Reproduced from Cash J. C., Glass, C. A., & Mullen, J. (Eds.). (2020). *Family practice guidelines* (5th ed.). New York, NY: Springer Publishing Company.

ULTRASOUND GUIDANCE

Ultrasonography has been recognized as one of the most effective diagnostic tools, not only with regard to identifying a radiolucent FB, but also in the removal of the FB (Tantray et al., 2018). US can help determine the depth and size of a FB. A high-frequency (13–6 MHz) linear-array transducer can be utilized, with or without a standoff pad. A standoff pad elevates the transducer off the soft-tissue surface, allowing for optimal sound transmission and improving the view of underlying soft tissue. Vessels can be easily identified with the US transducer. It is essential to survey the soft tissue adjacent to the FB site for local vessels in order to prevent vascular injury or excessive bleeding. Echogenicity of objects will vary depending on composition (**TABLE 23.1**). In general, FBs appear hyperechoic in the surrounding soft tissue. Wood and plastic may produce a shadow. A hypoechoic halo surrounding the FB is sometimes seen, which represents edema, abscess, or granulation tissue. Metal objects may produce a comet tail artifact. It is important to survey the entire field in both sagittal and transverse planes.

TABLE 23.1 **Foreign-Body Appearance With Ultrasound**

Foreign Body	Appearance
Gravel and wood	Acoustic shadow
Large wood	Brightly echogenic anterior surface
Metallic	Comet tail Reverberation artifact Bright parallel regularly spaced lines distal to the object
Glass	Acoustic shadow Comet tail Diffuse beam scatter
Retained FB (24–48 hours)	Echolucent halo

FB, foreign body.

Superficial Foreign Bodies

A near-field acoustic dead space can occur immediately adjacent to the transducer surface and impede the visualization of the superficial FB. Three methods help avoid this from occurring: the use of a US standoff pad, liberal use of the gel, and water-bath technique. The standoff pad is made of a low-acoustic-impedance material that elevates the transducer, eliminating the near-field acoustic dead space. These are commercially prepared pads, for example, the "Aquaflex ultrasound gel pad" (**FIGURE 23.11**). The water-bath technique allows the clinician to submerge the area in water and is useful for very sensitive areas or areas tender to palpation; the water bath allows use of the transducer against the affected area.

- Use a high-frequency linear-array transducer for superficial FB or low-frequency transducer for deeper tissue penetration.
- Apply a probe cover if an open wound is present.
- Use slow, methodical scanning in multiple planes to identify the FB (**FIGURES 23.12** and **23.13**).
- Once FB is identified, place the center of the probe over the FB and mark with a pen.
- Note the location and depth of the FB.
- Incise at the most superficial point of the FB.
- Advance splinter forceps toward the object while maintaining the image.
- Gently grasp the object and remove. (**FIGURE 23.14**)

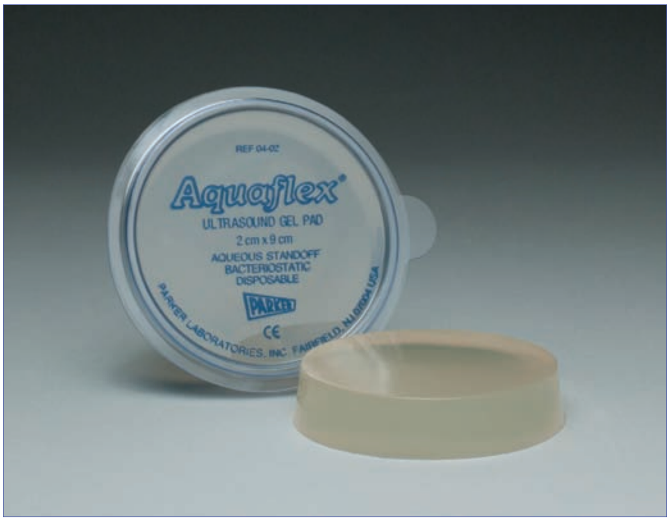

REF 04-02
Aquaflex®
ULTRASOUND GEL PAD
2 cm x 9 cm
AQUEOUS STANDOFF
BACTERIOSTATIC
DISPOSABLE
PARKER
CE
PARKER LABORATORIES, INC. FAIRFIELD, NJ 07004 USA

FIGURE 23.11 Photograph of a standoff pad.

Source: Reproduced by permission of Parker Laboratories.

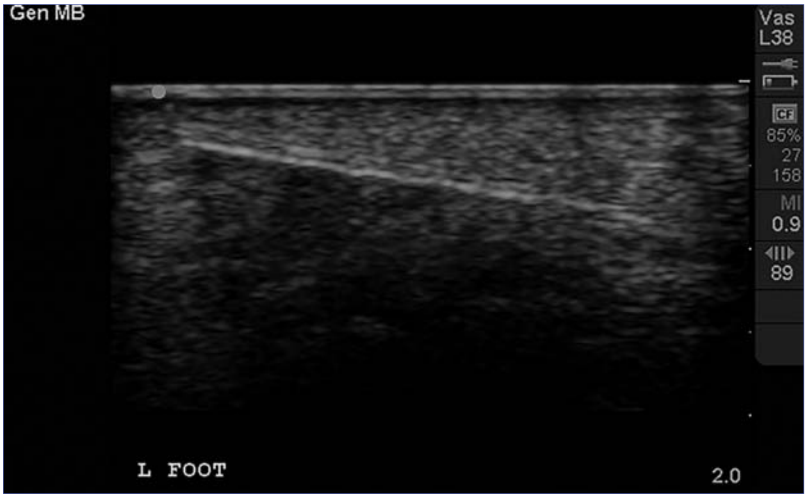

Gen MB
Vas
L38
CF
85%
27
158
MI
0.9
89
L FOOT
2.0

FIGURE 23.12 Ultrasound of foot with suspected wood foreign body.

FIGURE 23.13 Photograph showing removal of wood foreign body.

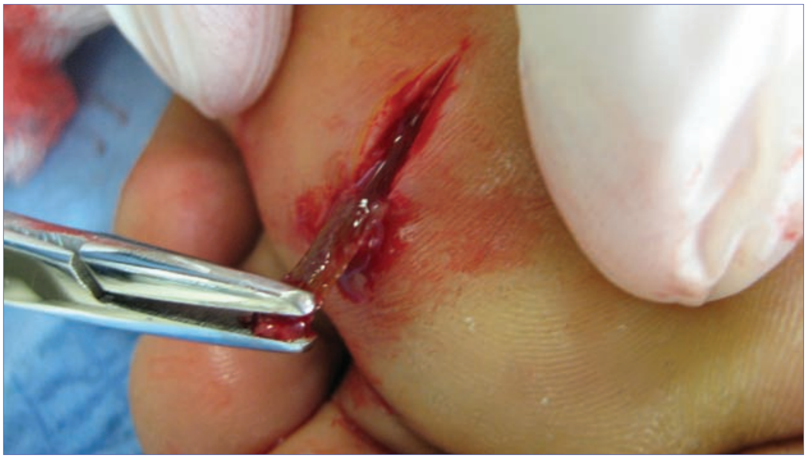
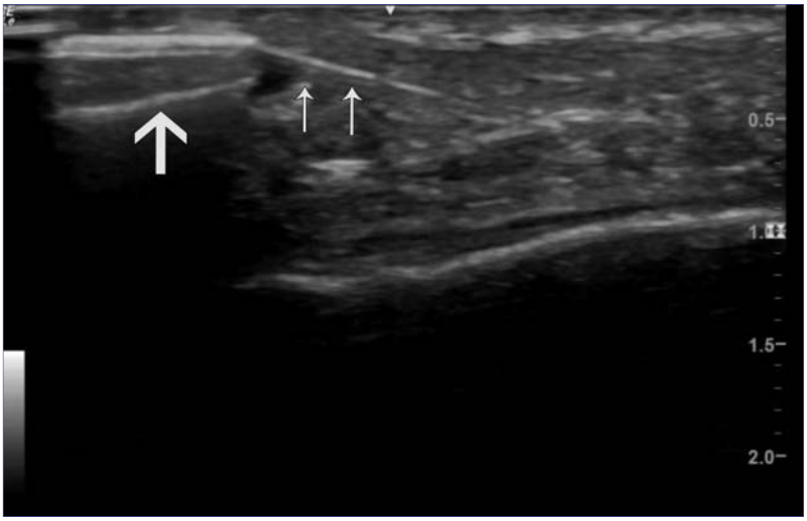


FIGURE 23.14 Ultrasound-assisted foreign-body removal. *Large arrow*: needle driver. *Small arrows*: foreign body.



- Evaluate the area with the transducer to ascertain any retained pieces. For deeper, irregularly shaped FBs, the needle localization method may be considered but is less suitable for sensitive structures of the hands and feet.
- High-frequency linear-array transducer is optimal for superficial FB; use low-frequency transducer for deeper tissue penetration.
- Apply a probe cover if an open wound is present.
- Use slow, methodical scanning in multiple planes to identify the FB.
- Once FB is identified, place the center of the probe over the FB.
- Insert one needle at a 45-degree angle to the FB.
- Inject lidocaine.
- Insert another needle at a 45-degree angle on the other side of the FB, making a 90-degree angle between the two needles.
- Make an incision and dissect down to the tip of the needle intersection.
- Grasp the FB and remove.
- Remove the needles.
- Scan the area to ascertain whether there are any retained pieces.

POSTPROCEDURE CONSIDERATIONS

- Need for tetanus prophylaxis should be assessed for all wounds.
- Copious irrigation is needed after the FB is removed.
- Marine spines (stingray, lionfish, and sea urchin) carry slime and calcareous material and are associated with granuloma formation—coverage for *Vibrio* infection should be considered. Depending on isolate consider doxycycline or fluoroquinolone (Gilbert, Chambers, Eliopoulos, Saag, & Pavia, 2018)
- A nail through a rubber-soled shoe should be followed for potential *Pseudomonas* infection. Osteomyelitis infection results in approximately 1% to 2% of plantar puncture wounds (Gilbert et al., 2018). Consider US evaluation or an x-ray to evaluate for radiopaque FB.

EDUCATIONAL POINTS

- Complete removal of the FB and irrigation are essential.
- Antibiotic prophylaxis and close follow-up for grossly contaminated wounds and for patients with comorbidity are recommended.
- Have the patient regularly clean the wound with soap and water and apply antibiotic ointment.

COMPLICATIONS

- Infection
- Retained FB
- Further injury
- Surrounding tissue affected during removal
- Neurovascular damage/compromise

PEARLS

- Education and counseling go a long way with patients with tick bites as most patients and/or parents are very anxious about the risk of Lyme disease and other illnesses. There are limited studies regarding antibiotic prophylaxis and the use of a one-time dose of doxycycline. The studies that have been done have shown that the incidence of transmission is low and the use of antibiotic prophylaxis inconclusive. Testing for Lyme disease should not be done immediately after the tick bite and/or after tick removal due to the high incidence of false results.
- Always use the proper type and amount of anesthesia before FB exploration.
- The use of a tourniquet for hemostasis aids in visualization and removal of FBs.
- A glove filled with US gel can be used in place of a commercial standoff pad.

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CHAPTER 24

Procedures for Managing Animal and Human Bites

Darlie Simerson

BACKGROUND

Animal and human bites commonly occur in all age groups and account for 1% of all ED visits. Animal bites in children usually occur from "roughhousing" or otherwise disturbing an animal. Most often, dog bites in adults are associated with trying to intervene between fighting dogs or while assisting a distressed animal. Dog bites are the most common animal bite, followed by cat bites. Human bites are less common and can be categorized as intentional (occlusive bite) or unintentional (closed fist to teeth). The overall objectives are to optimize wound healing, minimize functional and cosmetic deficits, and prevent or treat infection.

In 2008, there were an estimated 316,200 ED visits for dog bites in the United States. Dog bites occur most frequently in children 10 years or younger and most often involve the face, neck, or head. Bites to older children and adults usually occur on the hands and arms. Dog bites become infected 2% to 6% of the time, with bite wounds of deep dermal tissue becoming infected in up to 13% of these cases. The teeth of dogs are round and large and, in a large dog, can generate pressures from 200 to 450 pounds per square inch, which can result in crushing injuries. The presence of deep soft tissue, organ, bone, and tendon injury must be considered as well as foreign bodies that may be carried into the wound.

Cat bites are less frequent but have a much higher rate of infection with estimates varying from 30% to 50%, though this number may overrepresent the infection rate because many with bites that do not become infected likely never present for care. The teeth of a cat are sharp and pointed like a hypodermic needle and tend to "inoculate" bacteria deep into the tissue, creating a puncture wound. The tissue then closes, trapping bacteria inside the puncture. In addition, cat bites commonly occur on the hands, where risk of infection is greater. Although the wound may appear innocuous, an infection can develop quickly involving deep tissue, muscle, tendon, or bone. Evaluation for foreign bodies is essential as a cat's fine, pointed teeth can break off in the wound.

Human bites are less common but have a high rate of infection due to their polymicrobial (both aerobic and anaerobic) oral flora. These bites may occur from altercations, assaults, sexual activity, seizures, occupations involving medical or dental procedures, and children at play (**FIGURE 24.1**). Any open wound on the dorsal aspect of the hand, especially over the metacarpophalangeal joint of one or more of the fingers, should be strongly suspected to be a bite injury regardless of history. This often results from a clenched fist-to-tooth injury (*fight bite*) and is at high risk of becoming infected. This injury can result in purulent tenosynovitis, septic arthritis, or osteomyelitis. Rates of infection from human bites have been estimated to vary from 10% to 20%, with hand bites having a higher risk of up to 28%.

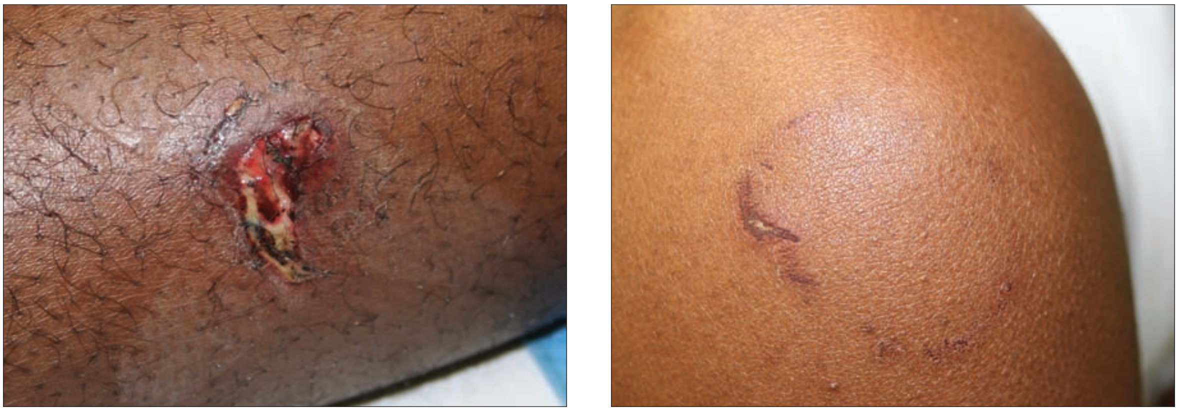

FIGURE 24.1 Photographs showing examples of human bite wounds.

PATIENT PRESENTATION

Patients with either human or animal bites can present with varying degrees of severity and associated injury. Obtaining a patient history regarding mechanism of injury can sometimes be challenging. Patients may deny a history of an altercation to avoid "getting in trouble." Some will avoid being forthright regarding animal bites for fear the animal will be removed or the owner will be penalized in some way. However, it is important to discuss the increased risk of infection possible with these injuries and to reassure the patient that he or she will not be penalized for being honest. It is important to document the discussion in the patient's medical record.

History

- Animal bite
  - History of how and when injury occurred: Provoked versus unprovoked attack
  - Type, size, age, wild or domestic, and health of animal
  - Current location of animal: Owned by or owner known to victim?
  - Immunization status of animal and victim
  - Victim health: Immunosuppressive conditions
  - Pain level: What alleviates or aggravates pain?
- Human bite
  - History of how and when injury occurred: Intentional versus unintentional
  - Immunization status of victim and person inflicting injury
  - Health of victim: Immunosuppressive conditions
  - Health of person inflicting injury: Medical history of HIV, hepatitis B virus (HBV), herpes simplex virus, syphilis
  - Pain level: What alleviates or aggravates pain?

Physical Assessment

- Wound description: Location, depth, size, and type of wound (abrasion, puncture, laceration, avulsion, crush injury)
- Associated characteristics: Tenderness, edema, ecchymosis, erythema, discharge, lymphadenopathy, foreign body
- Neurovascular status: Sensation, capillary refill, peripheral pulses
- Musculoskeletal status: Range of motion, strength, tendon integrity and function, bony deformities

TREATMENT

The goals of treatment are hemostasis, minimizing risk of infection, reducing edema, debridement of devitalized tissue, and improving cosmetic and functional outcomes. The risk of a retained foreign body is important to consider as this will delay healing and potentially lead to infection. Plain radiographic films should be considered to rule out both radiopaque foreign bodies and fractures/dislocations. Ultrasound is helpful if concerned about nonradiopaque foreign bodies.

Wound edges may need to be extended to properly visualize the extent of the wound, foreign bodies, and bone or tendon injuries. Extremity wounds should be examined through gentle range of motion to investigate for the presence of an injury that has retracted out of the field of view. Care must be taken not to create a complete tendon tear from a partial tear by using overvigorous wound or joint manipulation. This is most important when it comes to examining a clenched fist injury as the tendon must be examined in the position it was in at the time of the injury in order to detect a possible violation.

The degree of severity, age of injury, location, and type of bite will stipulate the treatment required. Minor bites may be treated with direct pressure to control bleeding, copious irrigation, topical antibiotic, and a dressing. One cannot diminish the role of copious irrigation in regards to proper wound management as it is a major means of infection prevention. A 19-gauge catheter/35-mL syringe provides adequate pressure (7 psi) and volume to clean most bite wounds. In general, 100–200 mLs of irrigation solution per inch of wound is required. Heavily contaminated bite wounds require even more irrigation. If available, povidone-iodine solution has been shown to be bactericidal and virucidal. A 10% solution can be diluted (10:1) and used to cleanse the surface of the wound as well as to irrigate; in this way, it will not damage tissue fibroblast cells (Garth, 2018). Major bites may require debridement as well.

Facial wounds should be closed by primary intention and may be accompanied by prophylactic oral antibiotics and close follow-up. However, facial wounds have a low risk of infection even when closed primarily due to their increased blood supply. A randomized clinical trial showed no increased risk of infection without the use of prophylactic antibiotics and improved wound healing times with primary closure of facial wounds from dog bites. Given the cosmetic implications of facial wounds, primary closure is therefore advisable. A study of dog bites has shown improved cosmetic scores and no increased risk of infection with primary closure of wounds in multiple anatomic locations along with the use of prophylactic antibiotics. Primary closure should only be considered in bite wounds that can be cleansed effectively. Bite wounds to the hands and lower extremities, with a delay in presentation (>8–12 hours old), or in immunocompromised hosts, generally should be left open or treated by delayed primary closure (Garth, 2018; Rui-feng, Li-song, Ji-bo, & Li-qiu, 2013). Most other bites will be allowed to heal by secondary intention. Recommended antibiotics for the common microorganisms found in dog, cat, and human bites may be viewed in **TABLE 24.1**.

Tetanus, rare in the United States, is caused by *Clostridium tetani* found in soil and the intestines of animals. The patient's tetanus immunization status should be assessed and tetanus toxoid in the form of tetanus with diphtheria (Td) and/or pertussis (Tdap) should be administered if over 10 years since last vaccine. Consider giving after 5 years if wound is "dirty." The decision on which vaccine to give is based on the patient's age and vaccine status. Please refer to the Centers for Disease Control and Prevention (CDC) immunization guidelines.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Age of Wound

- Delay in evaluation and treatment leads to increased risk of infection.
- Dog bites to the face can be sutured up to 12 to 24 hours after the bite secondary to the robust blood supply in this area. Antibiotic prophylaxis is recommended with follow-up in 24 to 48 hours.
- Bite wounds, other than facial, that are older than 8 hours should be left open to heal by secondary intention.

Cause of Wound

- Because of the increased risk of infection, human and cat bites should not be closed unless very large. This is especially true of bites to the hand.
- Do not irrigate puncture wounds with high pressure as irrigation fluid can become trapped and cause delayed healing or infection unless one extends the wound first.
- Do not use deep sutures in large wounds as this will increase the risk of infection.

History of Immunosuppressive Conditions

- Asplenic patients and those with diabetes mellitus, severe liver disease, HIV, and who are on immunosuppressive drugs should have close follow-up. Bite wounds for these patients should be allowed to heal by secondary intention unless gaping. These patients should receive a prophylactic antibiotic or admission for parenteral antibiotics.

SPECIAL CONSIDERATIONS

Consider consultation with plastic surgery for delayed or immediate primary closure in severe facial bites. This may be particularly important with facial bites to children. Also consider consultation with a hand surgeon for bites to the hand, especially cat or human bites. Infected human and cat bites to the hand, including "fight bites," should be referred to a hand surgeon for immediate follow-up or admission.

In small children, dog bites to the head may require additional evaluation with a CT scan of the head to make sure the skull was not penetrated. Skull and cervical spine radiographs may be indicated.

Patients requiring hospital admission include those in need of parenteral antibiotics or surgical debridement and repair. Immunocompromised patients with an infected bite may benefit from admission for parenteral antibiotics. Anyone with major trauma or blood loss may need admission.

Rabies should be considered with unprovoked attacks or with a suspicious bite when the offending animal cannot be located and quarantined or tested. Per the CDC (n.d.), healthy dogs, cats, and ferrets are not considered to be at risk for spreading the rabies virus. If the animal's rabies vaccine status is undetermined or none, the animal should be confined and observed for illness over 10 days. Rabies exposure risk for certain animal species is determined by local public health authorities. The animals most likely to be infected with rabies are raccoons, skunks, foxes, and bats. Rabies prophylaxis should be initiated as soon as possible if indicated and continued per specific scheduling guidelines. Please contact your local health department or the CDC for guidance.

The transmission of communicable diseases should also be considered for hepatitis, syphilis, and other infections. However, research has not shown the transmission of HIV but it is plausible. Whenever possible, the patient and person causing the injury should be tested.

PROCEDURE PREPARATION

- Absorbent under pad
- 1,000 mL sterile water or saline (recent studies have shown tap water is as safe and effective as more expensive solutions)
- 35- to 65-mL syringe
- Splash shield or 16- to 18-gauge angiocatheter
- Soap or surgical scrub (avoid povidone-iodine, ethyl alcohol, and hydrogen peroxide as these can further damage the tissue)
- 4 × 4 gauze
- Topical antibiotic
- Consider 1% lidocaine injectable, 3-mL syringe, 30-gauge needle if debriding
- Joint splints if indicated (foam finger splint)

PROCEDURE

Any bite to the hand along with any human or cat bite must be allowed to heal by secondary intention. This lessens the risk of infection. If the wound's size or location makes this strategy impossible, consider consultation with the appropriate surgical specialist. Primary closure is generally reserved for low-risk facial bites to optimize cosmetic outcomes. Otherwise, gaping bite wounds may be sutured with loose approximation to allow for partial secondary intention healing. Refer to Chapter 25, Procedures for Wound Closure, for more on closure techniques.

- Place absorbent pad under affected area.
- Draw up sterile saline or water into large syringe and attach splash shield or large-bore catheter.
- Irrigate area avoiding high pressure in small lacerations or punctures.
- Use a surgical scrub if needed to remove debris.
- Dry completely.
- Open wound edges and inspect for foreign bodies and tendon/bone injuries. The tendon must be inspected throughout its full range of motion to detect an occult violation.
- Apply topical antibiotic.
- Dress the wound.
- If debridement of devitalized tissues or deep inspection is necessary, consider anesthetizing area with 1% lidocaine using a small needle and injecting the lidocaine inside the wound edges after cleaning.
- Joint injuries should be splinted.

POSTPROCEDURE CONSIDERATIONS

Infection Prevention

Some bite wounds are more likely to become infected. Wounds requiring antibiotic prophylaxis include cat bites, hand bites of any type, all bite wounds that have closure by primary intention, contaminated wounds, crush wounds, joint capsule or bone involvement, and all immunosuppressed patients. Antibiotics prescribed must cover for *Pasteurella, Eikenella, Streptococci, Staphylococci*, and various anaerobes. These high-risk patients should receive prophylaxis with the antibiotic of choice, amoxicillin-clavulanate, for 5 to 7 days. If the patient is penicillin-allergic, a two-drug regimen is recommended. See **TABLE 24.1** for common organisms and appropriate antibiotic coverage.

Pain

Pain medication may be prescribed based on the severity of the injury and pain response exhibited. Nonsteroidal anti-inflammatory medications are recommended. Elevation with ice application may help alleviate pain by reducing swelling. Patients should understand that increasing pain may indicate a complication such as infection or compartment syndrome.

TABLE 24.1 Common Organisms and Antibiotic Treatment for Dog, Cat, and Human Bites

Bite	Organism(s)	First-Line Antibiotic	Alternatives if Penicillin Allergic
Dog	**Aerobic** *Corynebacterium* species (aerobic and facultative anaerobic) *Pasteurella multocida* *Staphylococcus aureus* *Streptococcus* species **Anaerobic** *Eikenella corrodens (facultative anaerobe)* *Capnocytophaga canimorsus*	Amoxicillin-clavulanate Prophylaxis: 3–5 days Infection: 10–14 days Parenteral therapy: Ampicillin/sulbactam	**Two-drug regimen: Aerobic + anaerobic coverage** Ciprofloxacin **OR** Trimethoprim–sulfamethoxazole **OR** Doxycycline **PLUS** Clindamycin **OR** Metronidazole
Cat	**Aerobic** *Pasteurella multocida* *Streptococcus* species (inc. *S. pyogenes*) *Staphylococcus aureus* *Moraxella catarrhalis* **Anaerobic** Fusobacterium *Bacteroides fragilis* Porphyromonas *Capnocytophaga canimorsus*	Amoxicillin-clavulanate Prophylaxis: 3–5 days Infection: 10–14 days Parenteral therapy: Ampicillin/sulbactam	**Two-drug regimen: Aerobic + anaerobic coverage** Ciprofloxacin **OR** Trimethoprim–sulfamethoxazole **OR** Doxycycline **PLUS** Clindamycin **OR** Metronidazole
Human	**Aerobic** Alpha and beta hemolytic streptococcus *Staphylococcus aureus* and *S. epidermidis* *Corynebacterium* species (aerobic and facultative anaerobic) **Anaerobic** *Eikenella corrodens (facultative anaerobe)* *Peptostreptococcus* species *Bacteroid fragilis* and nonfragilis *Fusobacterium* *Veillonella*	Amoxicillin-clavulanate Prophylaxis: 3–5 days Infection: 10–14 days Parenteral therapy: Ampicillin/sulbactam *No coverage for CA-MRSA	**Two-drug regimen: Aerobic + anaerobic coverage** Ciprofloxacin **OR** Trimethoprim–sulfamethoxazole **OR** Doxycycline **PLUS** Clindamycin **OR** Metronidazole

CA-MRSA, community-associated methicillin-resistant *Staphylococcus aureus*.

EDUCATIONAL POINTS

- Change dressing every 24 hours after first 24 hours.
- Wash the area with mild soap and water and apply antibiotic ointment.
- Apply antibiotic ointment to facial wounds frequently.
- Educate patient on signs of infection, including increasing pain, redness, discharge, and warmth to area.
- Educate patient on signs of compartment syndrome in extremity bite injuries, including increased pain, pale skin, weakness, numbness, tingling, and increased swelling.
- Stress importance of follow-up for reevaluation in the appropriate time span. Consider having patient return in 24 to 48 hours for recheck dependent on severity of injury and risk of infection.
- Advise caretakers that children must always be supervised around pets and must be taught never to handle unfamiliar or wild animals.
- For patients with risk factors for colonization with MRSA (IV drug users, sport teams, military personnel, recent hospitalization, dialysis), empiric coverage may be important.

COMPLICATIONS

Infection

The patient may not seek treatment until an infection is already present. Rapid onset of infection is usually indicative of *Pasteurella multocida*. If the wound was previously sutured, sutures must be removed. Antibiotics that were recommended for prophylaxis must be started, if not already, and given for a longer duration of 10 to 14 days. Close follow-up is important. Admission for parenteral antibiotics should be considered. Any hand-bite infection, including fight bites, must be referred immediately to a hand surgeon. Consider community-associated methicillin-resistant *Staphylococcus aureus* (CA-MRSA) infection in patients who are at risk to be colonized. Osteomyelitis must be considered if bone or joint space is invaded. See **TABLE 24.1** for further antibiotic considerations.

Other potential infection risks are considered depending on the type of bite. Hepatitis B (HBV) conversion is rare from a human bite but an offer of HBV vaccination or rarely HBV immunoglobulin can be made. *Capnocytophaga canimorsus* is an emerging bacteria found in the saliva of some dogs and cats and can cause septicemia, meningitis, and endocarditis if transmitted by bite. Cat-scratch disease, caused by *Bartonella henselae*, can be transmitted by cat bites and causes a pustule to form at the bite with development of regional lymphadenitis and fever usually 2 weeks later.

PEARLS

- Consider radiographic studies to rule out foreign bodies, bony injuries, and to evaluate possible osteomyelitis.
- Treat any hand injury as a bite injury if suspicious, especially if located dorsally over the metacarpophalangeal joints.
- Amoxicillin-clavulanate is the first-line antibiotic for all bite wounds for both prophylaxis and infection treatment.
- Most bite injuries can be left to heal by secondary intention unless facial. Lower risk facial bites can be closed for better cosmetic results.
- Common pitfalls are failure to identify foreign body, tendon injury, joint penetration, and immunosuppressed patients who are at higher risk for infection.
- Animal bites must be reported to authorities (police, animal control) in many locations.
- Rapid onset of infection is indicative of *Pasteurella multocida*.

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CHAPTER

25

Procedures for Wound Closure

Alecia S. Fox and Theresa M. Campo

BACKGROUND

The goal of a wound healing through primary intent is to achieve hemostasis, facilitate decreased healing time, reduce the risk of infection, and minimize scarring/optimize cosmetic result. This can be achieved through rapid assessment and interventions that minimize contamination. These strategies include debriding devitalized tissue, obtaining hemostasis, removal of any foreign body, revising wound edges (if needed), and approximating tissue edges. It is imperative to make an accurate and thorough assessment, not only of the wound, but also of the circumstances that led to the wound (mechanism and time). It is also important to assess for past medical history, allergies to anesthetics, neurological and motor function, presence or suspicion of foreign body, and underlying structural damage (tendon, vessel, joint capsule, and nerve).

Delay in wound healing can have multifaceted consequences. The mechanism of the injury alone (i.e., crush, foreign body) can put the patient at risk for infection and complication. Medical conditions and medications also play a role in wound healing. Patients with diabetes, immunosuppression, obesity, malnutrition, tobacco use, older age, and steroid usage are at greater risk for infections and delayed wound healing. It is important to help the patient to manage these risk factors whenever possible. The provider must critically assess each wound and identify the most appropriate approach, depending on a multitude of issues relating to wound characteristics, patient factors, and technical expertise.

PATIENT PRESENTATION

- Pain
- Bleeding
- Open wound(s)
- Decreased or loss of sensation or function
- Anxiety

TREATMENT

Treatment begins with a thorough history, including mechanism, time of incident, medications, medication allergies, and tetanus immunization status. In regards to wound closure timing, it is important to note that, up to this point, no randomized controlled trials have compared primary and delayed closure of non-bite traumatic wounds. One systematic review of 2,343 patients found that lacerations repaired after 12 hours have no significant increase in infection risk compared with those repaired earlier. Also, a case series of 204 patients found no increased risk of infection in wounds repaired at less than 19 hours. Non-infected wounds caused by clean objects may undergo primary closure up to 18 hours after injury while head wounds may be repaired up to 24 hours after injury (Forsch, Little, & Williams, 2017; Zehtabchi, Tan, Yadav, Badawy, & Lucches, 2012). Once the history is complete, do a careful examination of the wound and surrounding areas to ensure that there are no hidden foreign bodies or other injuries. Suspicion for a foreign body should be further evaluated with plain radiograph or ultrasound. Regardless of the size of the wound, the patient will experience pain and should be anesthetized before wound cleansing and exploration.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

First, cleanse the skin. The area should then be anesthetized and irrigated with moderate pressure (5–8 pounds per square inch [psi] with normal saline irrigation), and/or gently scrubbed. A Cochrane review (Fernandez & Griffiths, 2012) composed of three adult studies and two pediatric studies compared the rates of wound infection from the use of tap water versus normal saline solution (NSS) for acute wound cleansing. Among the 1,863 participants, tap water irrigation was shown to be non-inferior in regards to later wound infection development compared to NSS irrigation. Another study (Weiss, Oldham, Lin, Foster, & Quinn, 2013), a double-blind randomized controlled trial published after this Cochrane review, found similar results. In the 663 participants studied, there was no difference between those irrigated with tap water versus normal saline, with a trend toward decreased infections in the tap water group. Once cleansed, probe the wound for debris, foreign body, and devitalized tissue. The type of closure used will depend on the type of wound, location, time since injury, contamination, and depth. Novel noninvasive closure devices and expanded use of skin adhesives have become competitive options in addition to traditional sutures for closure of wounds under tension. These innovations have facilitated more rapid and less painful closure of wounds. This chapter includes discussion of suture, staple, skin adhesive, and tape closures. The beginning of each procedure section includes the advantages and disadvantages of each method. With all methods of wound closure, eversion of the wound edges is of paramount importance, as the wound contracts during the healing phase.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Grossly contaminated wounds
- Cause of the wound(s)
  - Puncture wound
  - Human and animal bite (depending on source and location)
- Delay in seeking treatment—Lacerations in healthy patients may be closed up to 18 hours following the injury without a significant increase in the risk of wound infection
  - Face and scalp: Increased risk after 24 hours
  - Hands and feet: Increased risk after 6 hours

SPECIAL CONSIDERATIONS

- Diabetes and chronic renal failure
- Immunosuppression
- Tobacco use
- Steroids and blood-thinning medications
- Chemo and radiation therapies
- Malnutrition (includes underweight and obesity)

PROCEDURE PREPARATION

- Nonsterile gloves
- Absorbent pad
- 4 × 4 gauze
- Skin cleanser (pH neutral)
- Topical anesthetic (i.e., LET gel [lidocaine 4%, epinephrine 0.1%, and tetracaine 0.5%])
- Injectable anesthetic
- Normal saline for irrigation
- 20- to 30-mL syringe
- Splash guard
- Surgical scrub
- Nonadherent gauze
- Topical antibiotic

Suture

- Sterile gloves
- Suture kit (needle holder, toothed forceps, suture scissors, sterile drapes, basin and cups for cleanser, and normal saline)

- Suture material
  - Subcuticular and subcutaneous—Absorbable (vicryl, chromic)
  - Percutaneous—Nonabsorbable (nylon, polypropylene)
  - Face—Thinner material (6–0)
  - Extremities, torso, and scalp (3–0 to 5–0)

Staple

- Sterile gloves
- Suture kit (needle holder, toothed forceps, suture scissors, sterile drapes, basin and cups for cleanser, and normal saline). For scalp lacerations, hair may be clipped with scissors or held away from the wound with sterile, water-soluble lubricant.
- Staple gun

Skin Adhesive

- Sterile pack 4 × 4 gauze
- Skin adhesive (Cyanoacrylate glue—Dermabond, Indermill)
- Skin tape (Steri-Strips, butterflies)

Tape

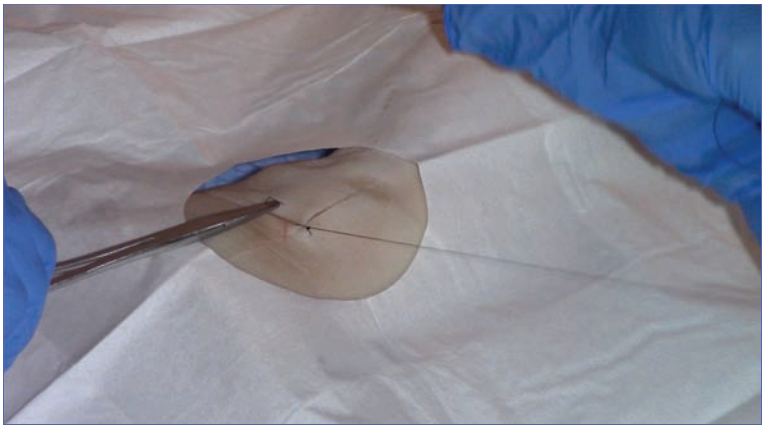
- Benzoin
- Cotton-tipped applicators
- Skin tape (¼ inch, ½ inch)

PROCEDURE

Suture

Suturing is a great method of wound closure that offers precise wound-edge approximation and tensile strength. The disadvantages of sutures are the need for injectable anesthetic, removal of the sutures, tissue reactivity (especially with absorbable sutures), increased cost, and increased time to perform the procedure. There is also a great expectation by the patient or parents for a "perfect closure" and no visible scar formation (**VIDEO 25.1**).

- Put on nonsterile gloves.
- Cleanse the skin.
- Apply topical anesthetic.
  - This is especially effective on face wounds and in children.



VIDEO 25.1 Simple interrupted suture.

- Perform local, digital, or regional block based on the location and size of the wound (see Chapters 16, 17, and Chapter 18).
- While the anesthetic is taking effect, open the suture kit and place the equipment needed onto your sterile field.
- Put on sterile gloves.
- Draw up the normal saline for irrigation in the large syringe.
- Attach the splash guard.
- Irrigate the wound with moderate pressure: 5 to 8 psi, which can be achieved using a 35- to 65-mL syringe and either a splash shield or 16- to 18-gauge angiocatheter.
    - Use a gentle scrub for the eyebrow and around the eye as pressure irrigation can cause further damage to this sensitive area.
- Gently scrub the area if there is debris and contamination that was not removed with irrigation.
- Place the fenestrated sterile drape over the wound.
- Probe and visualize the wound for debris, contamination, and devitalized tissue; if found, remove.
- Open the suture material.
- Hold the needle holder in your dominant hand with the thumb in one hole and the ring finger in the other (**FIGURE 25.1**).
- Using your index finger to support the needle holder, open the locking mechanism.
- Grab the suture needle at the junction of the proximal section and midsection.
    - The needle holder should be perpendicular to the needle (**FIGURE 25.2**).
- Secure the locking mechanism.
- Remove your fingers from the holes and hold the needle holder in the palm of your hand.
- Put the forceps in your nondominant hand between the thumb and index fingers (**FIGURE 25.3**).
- Use the forceps to gently evert the wound edge.
- Insert the needle at 90 degrees to the skin (**FIGURE 25.4**) and press the needle through the skin and out the center of the wound. This angle ensures proper skin–edge eversion.
    - Supinate your hand to give the proper motion and direction through the skin.
- Release the needle.
- Grab the needle with either the forceps or needle holder, pull through the wound, and reposition the needle holder on the needle as described previously.
- Use the forceps to evert the opposite side of the wound.
- Push the needle through the inside of the wound adjacent to the first insertion and push through the skin at the same distance from the wound on the opposite side, entering the tissue at a 90-degree angle (**FIGURE 25.5**).
- Grab the needle with either the forceps or needle holder with the needle holder approximately 1/3 the distance from the eye and 2/3 from the point.
- Pull the material through the tissue leaving a 1- to 2-cm tail.

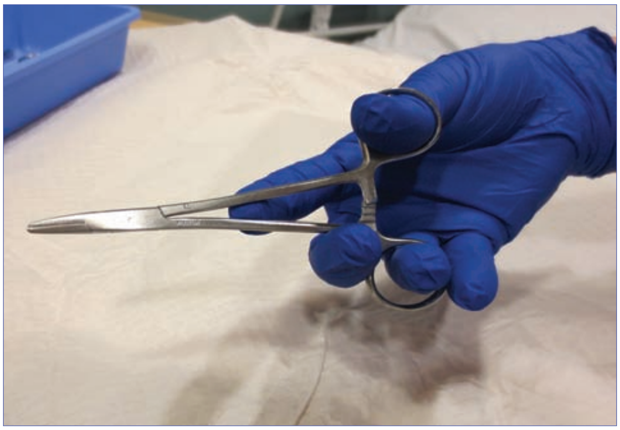


FIGURE 25.1 Proper way to hold a needle holder.

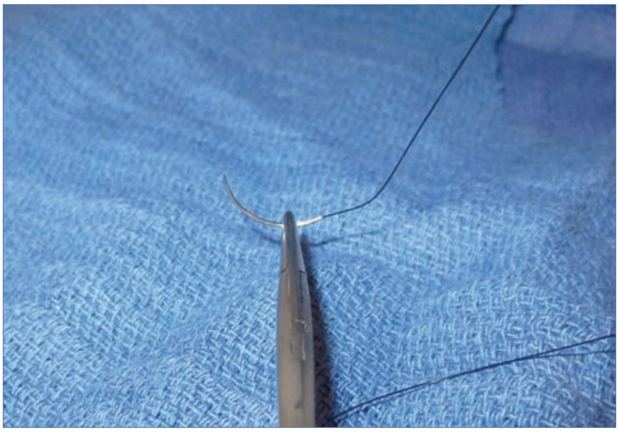


FIGURE 25.2 Proper way to hold a suture needle with the needle holder.

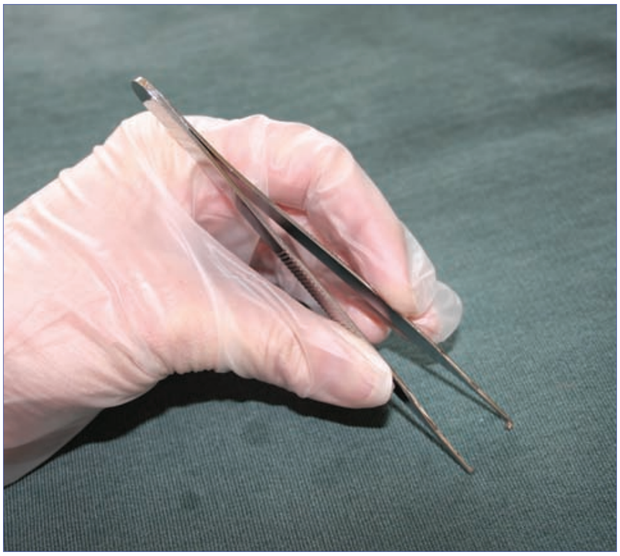


FIGURE 25.3 Holding the forceps.

- Place your needle holder parallel to the wound (**FIGURE 25.6A**).
- Loop the needle at the end of the material two times and then grasp the tail with the needle holder and pull across, keeping the twist flat (**FIGURE 25.6B**).
- Place the needle holder parallel over the wound and loop one time in the opposite direction.
- Grasp the tail and pull across—again, the twist should be flat.
    - Approximate the wound edges, being careful not to "strangulate" the wound edges (**FIGURE 25.6C**).

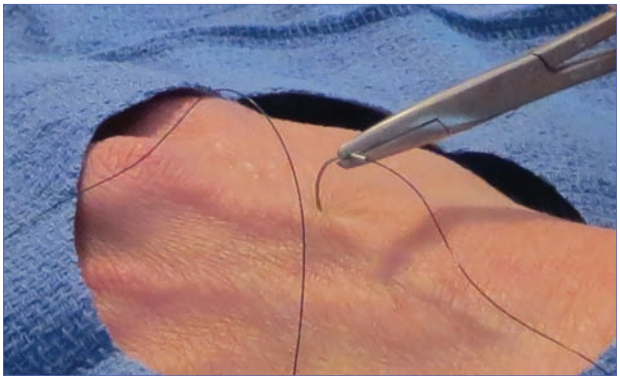


FIGURE 25.4 Inserting the needle at 90 degrees.

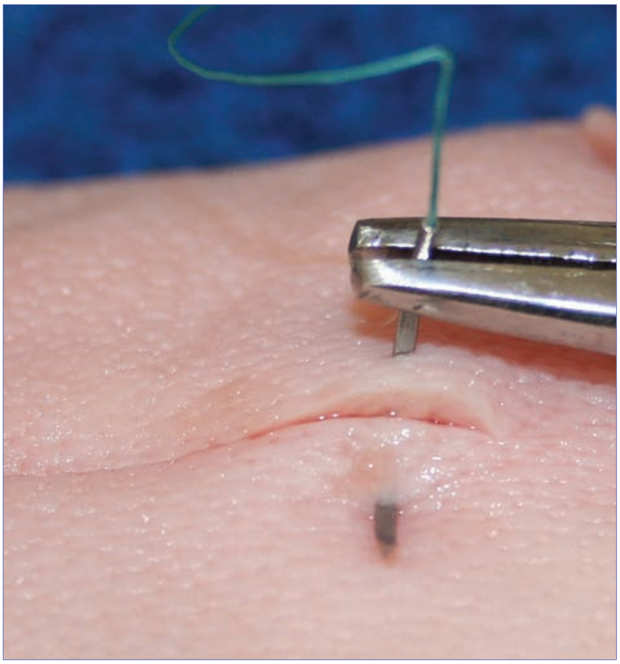


FIGURE 25.5 Needle going through the other side. Note the equidistant area on each side of the laceration in regards to needle entry and exit points. Also, unlike depicted in this photo, the needle should be grasped with the needle holder approximately 1/3 the distance from the eye and 2/3 from the point.

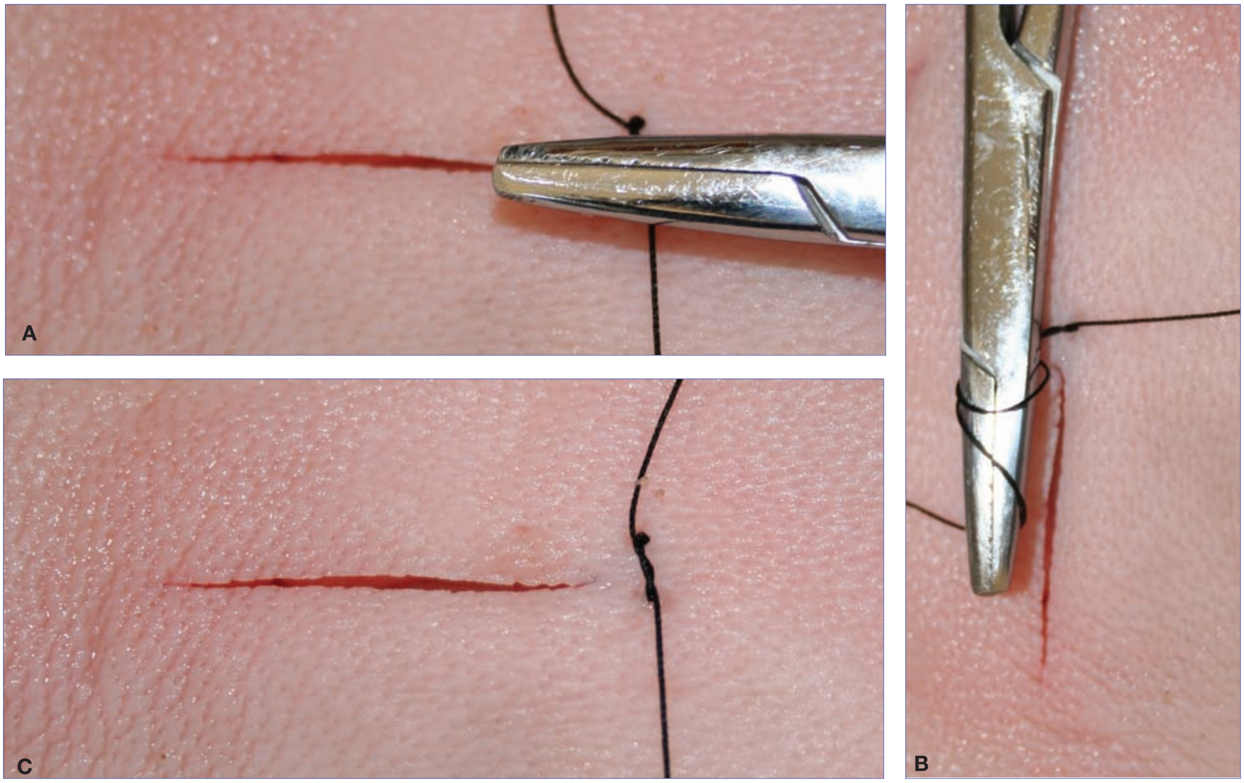


FIGURE 25.6 Tying a suture knot. (A) Place the needle holder parallel to the wound; (B & C) loop the needle at the end of the material two times and then grasp the tail with the needle holder and pull across, keeping the twist flat and approximating the wound edges.

- Repeat the aforementioned two steps. Once tied, each knot consists of three (total) ties (the first winds suture twice, the second and third tie winds suture only once) thrown in opposite directions perpendicular to the wound edge.
- Knot(s) should be to the side of the wound and not directly over the wound itself.

Simple Interrupted Suture

- Snip both ends of the material approximately 1 cm above the knot.
- Repeat these steps as many times as needed.
- Appropriate spacing (**FIGURE 25.7**):
  - Allow equal space from the entry point to the wound and the wound to the exit.
  - Allow equal space between the sutures. A useful guideline is that the distance between sutures is equal to the bite distance from the wound edge.
- Start in the center and work your way out to the edges on each side, or start at one end and finish on the opposite side.

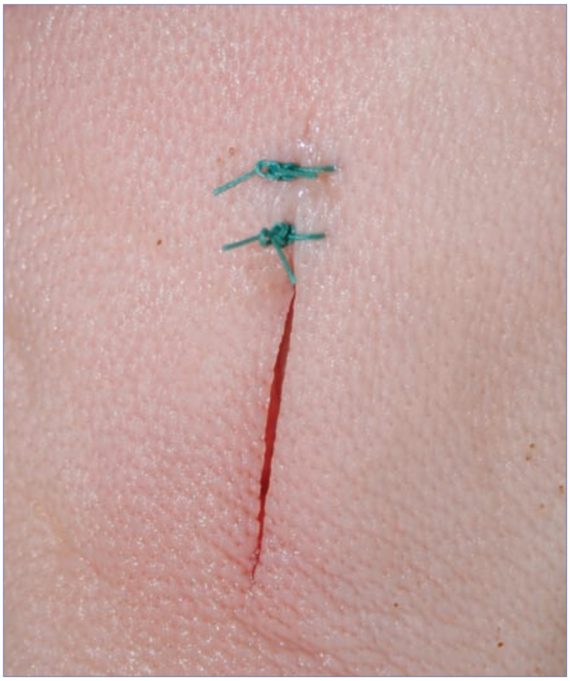


FIGURE 25.7 Appropriate spacing of a suture. Note the distance between sutures is equal to the bite distance from the wound edge.

Continuous Suture (Also Known as a *Running Suture*)

- Snip only the tail end to approximately 1 cm.
- Insert the needle beside the first insertion and come out on the other side of the wound.
- The needle will be inserted each time on the same side of the wound with equal distance between bites. Continue the entire length of the wound.
- When you have made your last pass through the wound, do not pull the material all the way through; leave a loop.
- Make a knot as described previously, grabbing the loop in place of the free tail (**FIGURE 25.8**). Check the alignment of the unsutured wound edges for potential misalignment, which is known as *dog-ears*.
- Continuous sutures take less time but if one area breaks, then they all break. Intermittently locking the suture with a knot can help prevent this from occurring (**VIDEO 25.2**).

NOTE The number of sutures needed to close a wound varies depending upon the length, shape, and location of the laceration. In general, sutures are placed just far enough from each other so that no gap appears in the wound edges. A useful guideline is that the distance between sutures is equal to the bite distance from the wound edge.

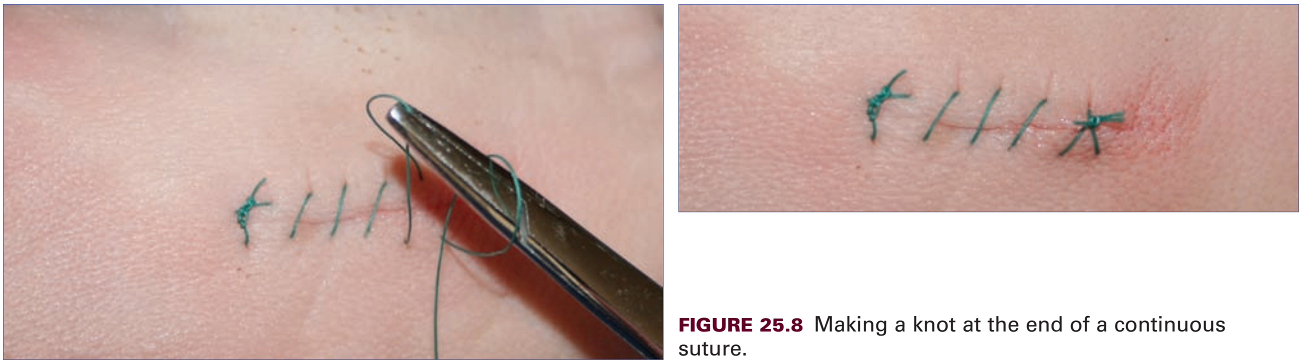
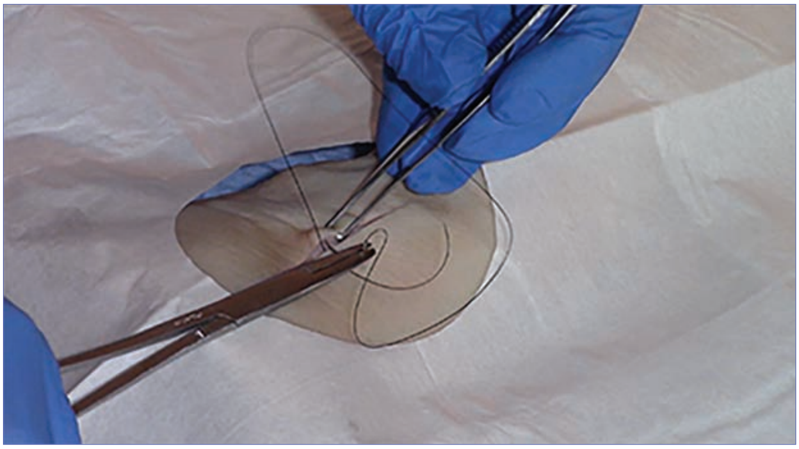


FIGURE 25.8 Making a knot at the end of a continuous suture.

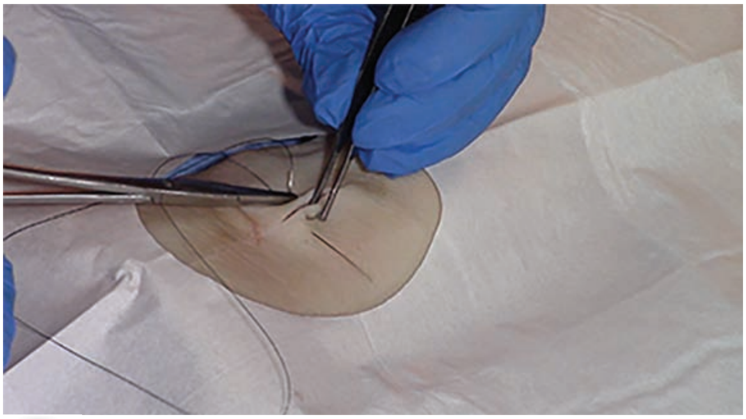


VIDEO 25.2 Continuous suture.

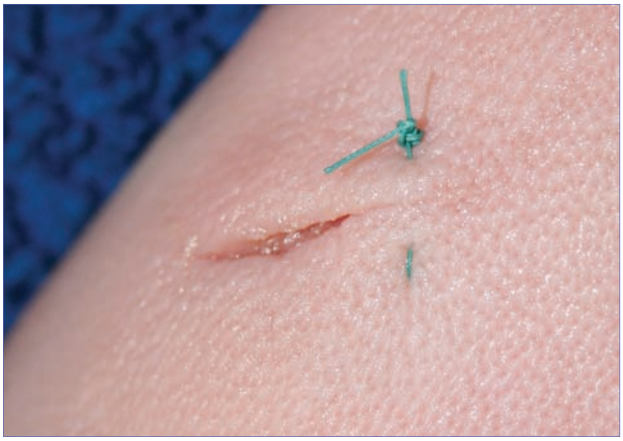
Vertical Mattress Suture

This method promotes eversion of the wound edges for healing and is best used in areas where inversion easily occurs (i.e., palmar surface of hand). This method has two components. The first component is used for wound tension and is deep into the dermis, and the second component is superficial and everts the wound edges. These components allow for a meticulous wound-edge approximation (**VIDEO 25.3**).

- Insert the needle 4 to 8 mm from the wound edge.
- Push through the skin and wound as described previously, keeping the exit the same distance from the wound as the insertion.
- Turn the needle around and insert it between the exit and the wound, and come out the other side between the wound edge and the insertion (**FIGURE 25.9**).
- Tie a knot as described previously (**FIGURE 25.10**).
- Repeat as necessary.



VIDEO 25.3 Vertical mattress suture.



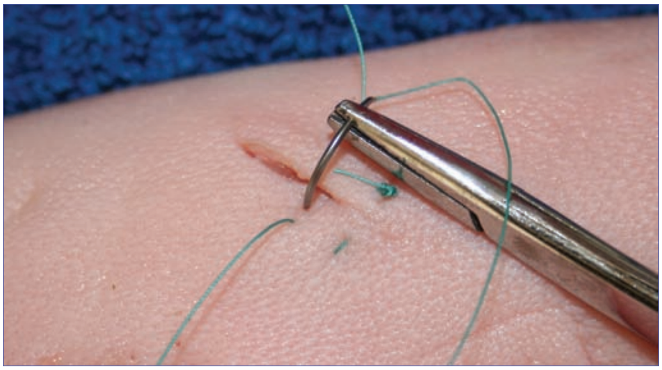


FIGURE 25.9 Performing a vertical mattress suture.

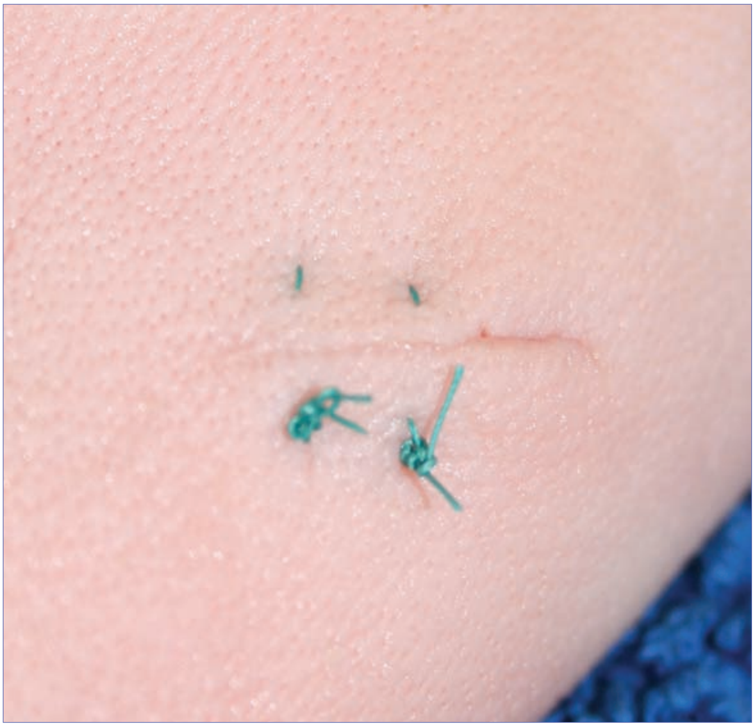


FIGURE 25.10 Completed vertical mattress suture.

Horizontal Mattress

- Insert the needle perpendicular into the skin (about 4–8 mm from the laceration edge).
- Pass the needle through to the opposite laceration edge and exit.
- Place the needle backward in the needle driver and insert into the skin (about 4–8 mm matching the above distance) farther down the wound edge (the edge where the needle has just been passed through) and pass from the far side of the laceration back to the near side.
- The needle should exit the laceration about 4 to 8 mm below the original wound edge from the original insertion site, matching the above distances creating a "square".
- Tie the suture gently on the side of the laceration where the suturing began.
- Repeat as necessary to cover the entire area of the laceration (**FIGURE 25.11**).

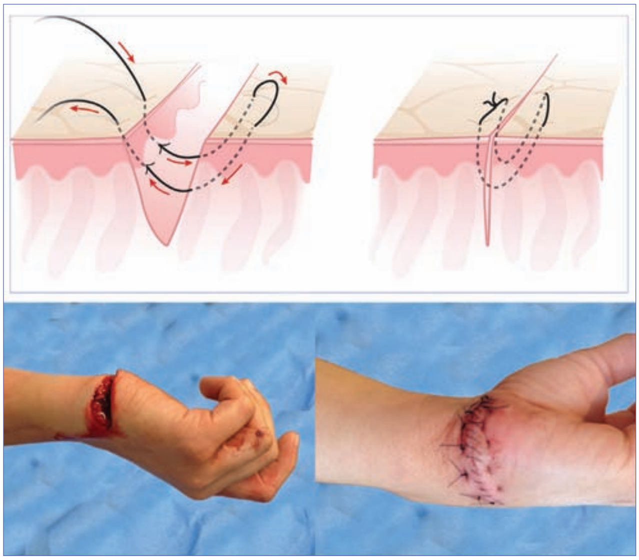
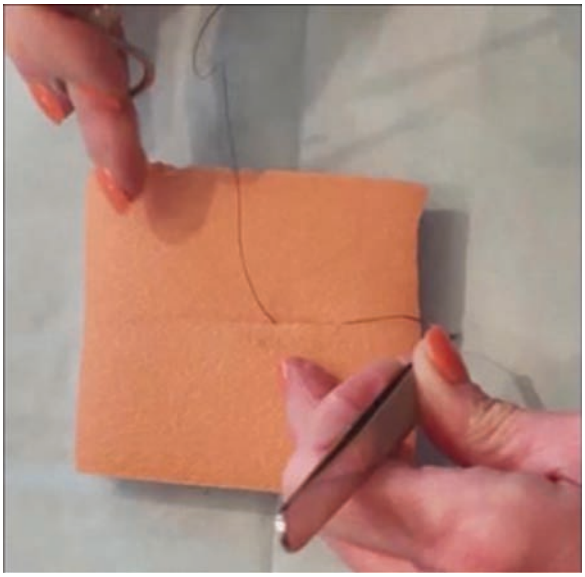


FIGURE 25.11 Horizontal mattress suture. Note in the completed laceration repair, it is shown intermixed with a running suture. Horizontal mattress sutures are generally used in high tension wounds (such as the one depicted) as they spread the tension along a wound edge. In this manner, this technique is commonly used for pulling wound edges together over a distance, or as the initial suture to anchor two wound edges together.

Deep Suture Technique A

- Insert the needle into the dermal layer at one end of the wound and exit toward the center of the wound (**VIDEO 25.4**; **FIGURE 25.12**).
- Insert the needle adjacent to the exit and push through adjacent to the first entrance (making a circle).
- Tie a knot as previously described.
- Repeat as necessary to close the dermal layer of the wound.



VIDEO 25.4 Performing a deep suture technique A suture.

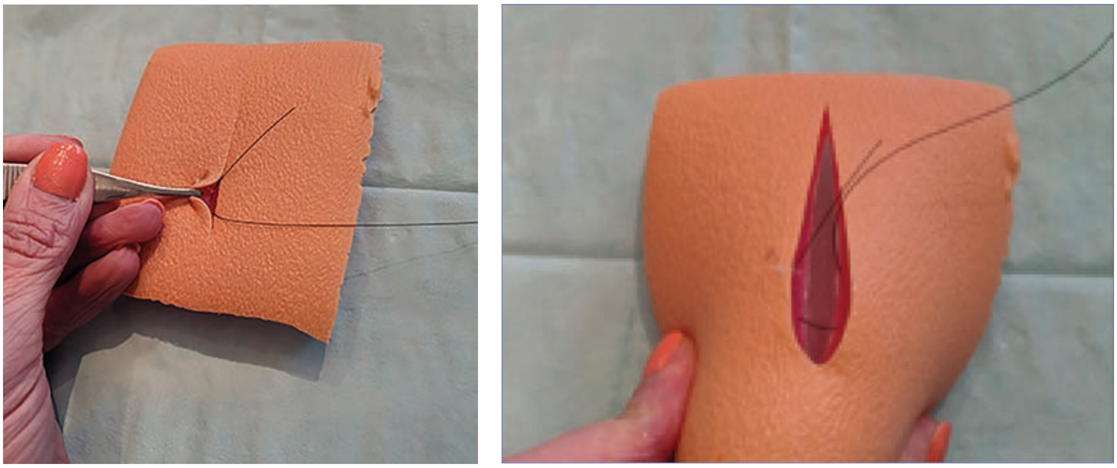
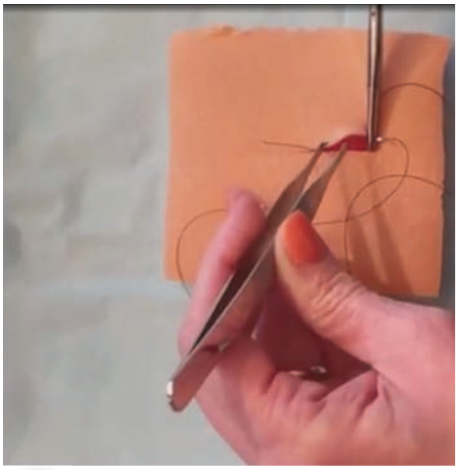


FIGURE 25.12 Performing deep suture technique A.

Deep Suture Technique B

- Insert the needle at the base of the subcutaneous tissue and exit just above it (**VIDEO 25.5**; **FIGURE 25.13**).
- Insert the needle adjacent to the exit and push through to the base of the subcutaneous layer (adjacent from the first insertion).
- Tie a knot as previously described.
- Repeat as necessary to close the deep space.

Skin adhesive can be applied or fine percutaneous sutures can be added to close the percutaneous layer.



VIDEO 25.5 Performing a deep suture technique B suture.

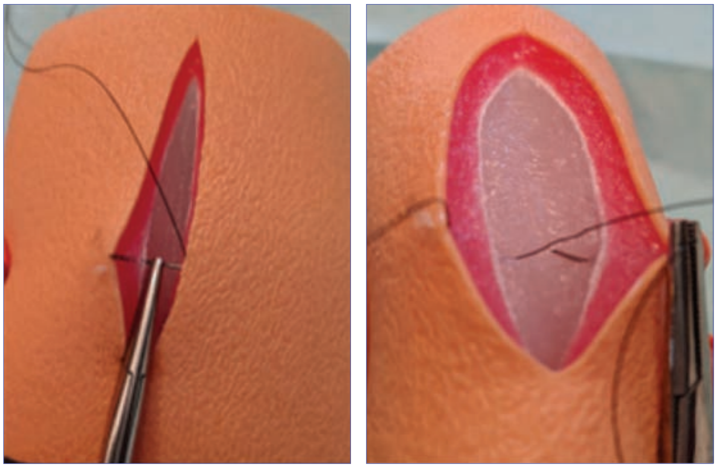


FIGURE 25.13 Performing a deep suture technique B suture.

Staple

The benefits of using a staple closure include minimal time required for the procedure, decreased tissue reactivity, and decreased cost compared to suture closure. However, the provider does not have the same control with this method of closure and the staples can interfere with some radiological studies (i.e., CT scan and MRI). Staples should not be used on the face.

- Have an assistant hold the everted wound edges with forceps.
- Place the stapler perpendicular to the wound, with the center of the stapler directly over the wound.
- Press down as you squeeze the trigger and place the staple.
- Repeat as necessary.
- Spacing should be equal, as with sutures (**FIGURE 25.14**).

Skin Adhesive

Skin adhesives are easy to use, painless, and are a cost-effective method of closure, and are ideal for superficial and small lacerations. Topical or injectable anesthetics are not required for this method of closure. Skin adhesives are water-resistant and should not be placed over joints, mobile areas, or moist areas. If placed on wounds with high tension or skin-edge distance that have a greater chance of dehiscence than suture or staple closures, subcuticular or subcutaneous sutures should be placed first. As a rule of thumb, if the wound edges are not easily opposed via minor tension or would otherwise need to be closed via a suture size greater than 5-0, the dehiscence rate surpasses that of using a suture material for skin closure; in this regard, one may first place subcuticular or subcutaneous sutures in order to alleviate wound tension prior to placing the skin adhesive. Skin adhesives can take 24 hours to gain full maximum strength and last 5 to 7 days before tensile strength decreases rapidly secondary to breakdown. Cosmetic outcomes have been found similar to sutured wounds, while time of procedure is much shorter, making this an advantageous closure technique in selective cases (**FIGURE 25.15**).

- Irrigate and cleanse the area. Cosmetic outcomes have been found similar to sutured wounds, while time of procedure is much shorter, making this an advantageous closure technique in selective cases.
- Dry completely.
  - Any moisture, including blood, will hinder the skin adhesive from working.

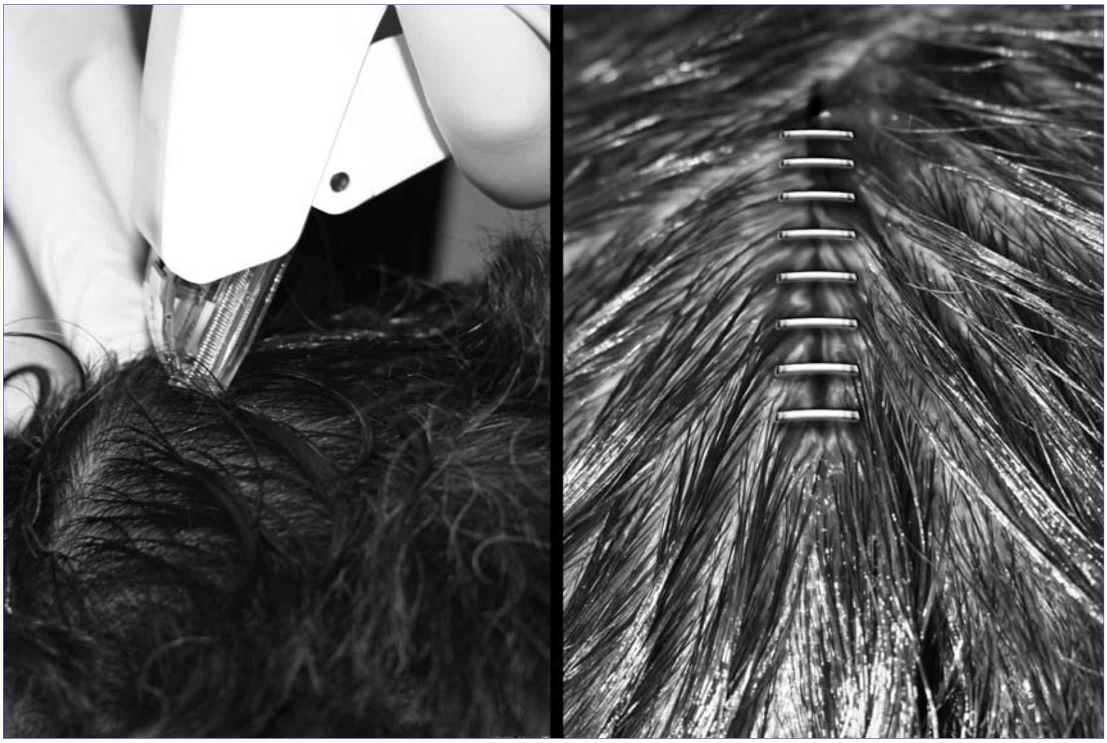
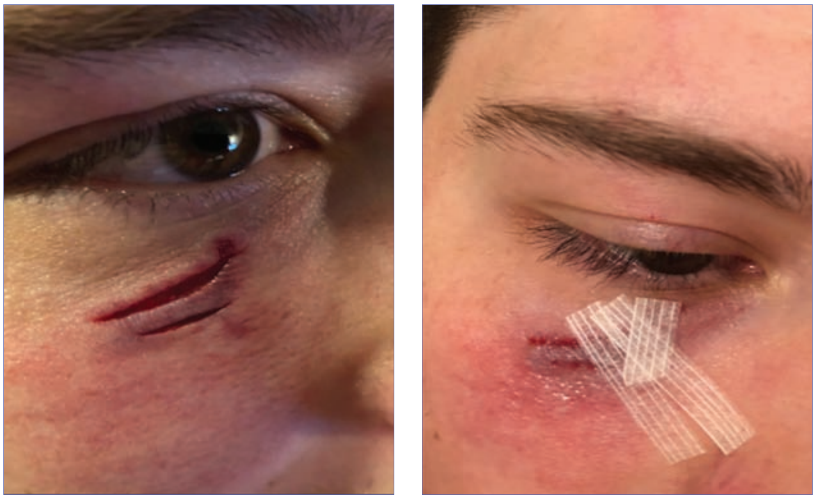


FIGURE 25.14 Performing a staple closure (note the equal spacing).

FIGURE 25.15 Closure with skin adhesive and tape.



Courtesy Alecia Fox.

- Approximate the wound edges.
- Apply the adhesive to the wound. Do *not* place skin adhesive inside the wound as this may cause a foreign-body reaction.
- Never place antibiotic ointment or cream over the skin adhesive as it will hasten breakdown.
- Allow to dry.
- Applying skin tape to the area is optional.

Skin Tape

Skin tape is ideal as a primary closure for superficial wounds, as well as reinforcement of suture, staple, and glue closures. When used alone, it tends to fall off prematurely and causes the highest rate of wound dehiscence compared to other methods of wound closure (**FIGURE 25.16**).

- Irrigate and cleanse the wound as described previously.
- Dry the area thoroughly.
- Dip the cotton-tipped applicator into the benzoin.
- Apply to the wound edges.
- Allow to dry.
- Cut the tape to fit the wounds, allowing approximately 1 cm on each side of the wound.
- Approximate the wound edges.
- Stick the tape to one side of the wound and gently pull to the other side (this will aid in the approximation). If placed under too much tension, it is possible to shear the skin and cause blistering.
- Repeat as necessary the entire length of the wound.

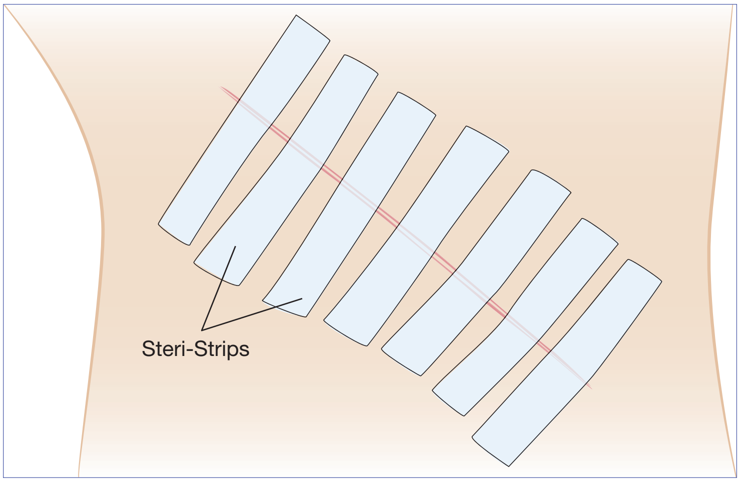


FIGURE 25.16 Closure with skin tape.

POSTPROCEDURE CONSIDERATIONS

Bleeding

- Bleeding and "oozing" from a sutured or stapled wound can be common.
- Elevate the wound and apply direct pressure.
- Light-pressure dressings can be applied to the wound.

Antibiotic Prophylaxis

- If the wound is older than 8 hours or grossly contaminated, antibiotics may be prescribed unless the wound is on the face or if edges will be excised before closure.
- Antibiotics may be given to patients with diabetes or immunosuppression, or those on steroids.

Pain

- Closure, dressings, elevation, and immobilization (splint) of joints with wounds will help decrease pain.
- Pain medication can be prescribed, if necessary, based on the patient's pain tolerance and extent of the wound.
- Nonsteroidal anti-inflammatory medications should be avoided as they have been linked to delayed healing.

EDUCATIONAL POINTS

Wound Care

- Avoid dressing changes for 24 hours to help the healing process and the laying down of granulation tissue.
- Instruct the patient to clean with soap and water, and to avoid antiseptics (betadine, alcohol, and hydrogen peroxide) as these can hinder the healing process.

Follow-Up

- Wound reevaluation is recommended in 48 hours.
- Follow-up with a specialist is needed for any wounds with tendon, nerve, or deep-structure involvement.

COMPLICATIONS

- Infection is always a risk, even with timely irrigation, closure, and dressing of the wound.
- Patient's instructions should include return precautions for signs of infection: redness, swelling, pain, pus, fever, and red streaks.

PEARLS

- When considering the type of closure, choose the least invasive method with the best chance for an optimal result.
- When dealing with children and parents, remember that this is an anxiety-producing event. Frequent reassurance and a confident attitude go a long way. Encourage the child's caregiver to remain calm and focus on providing reassuring support to the child.
- When performing a procedure on a child or on a complex wound, try to focus only on the wound. Elicit additional staff to provide assistance as needed.
- With jagged, uneven wounds, strategically place sutures to match up wound edges. Remember that if you do not like the way it is closing or the tension is not what you expected, there is nothing wrong with removing the suture and replacing it.
- Open communication with the patient, even when the patient is a child, is very important. Do not ever lie to a patient or parent or try to "candy coat" what you are going to do. Establishing and building a trusting relationship is important.
- You can place skin adhesive over sutures to help keep children from pulling out knots.
- In general, secondary wound infection occurs 24 to 72 hours after the initial injury. Hence, schedule a 48-hour wound check follow-up.
- All wounds contain a foreign body until proven otherwise with proper exploration.
- Wound anesthesia should precede wound cleansing.
- The use of nonsterile gloves during laceration repair does not increase the risk of wound infection compared with sterile gloves, according to many studies.
- Irrigation with tap water rather than NSS does not increase the risk of wound infection, according to many studies.
- Local anesthetic with epinephrine is safe for use on digits, ears, and the nose.
- Tissue adhesives can be used effectively in low-tension skin areas.
- Head wounds may be repaired up to 24 hours after injury.
- Factors that may increase the likelihood of infection include wound contamination, laceration length greater than 5 cm, laceration located on the lower extremities, and diabetes.
- Compared with multilayer repair, single-layer repair has similar cosmetic results for facial lacerations
- Running sutures reportedly have less dehiscence than interrupted sutures in surgical or linear wounds.
- Vertical mattress sutures are effective for everting wound edges.
- Horizontal mattress sutures are useful for everting edges of uneven tissue heights in flap repairs.

LIP LACERATION INVOLVING THE VERMILION BORDER OR INTRAORAL CAVITY

SPECIAL CONSIDERATIONS/CLOSURES

Lip lacerations occur frequently from falls, assaults, animal bites, and motor vehicle crashes. The goal of treatment is a good cosmetic outcome and hemostasis. The lips are composed of three layers: skin, muscle, and oral mucosa. The vermilion border is the area that separates the lip and skin. Unlike facial skin, its stratified squamous epithelium does not contain keratin and has fewer melanocytes. For this reason, underlying blood vessels are more apparent; hence, the red color. Improper closure can lead to disfigurement. Wounds that extensively involve large pieces of the vermilion border and/or where the commissure is missing (junction where the upper and lower lips join) should always have plastic surgery repair.

PROCEDURE PREPARATION

- Nonsterile gloves
- Absorbent pad
- 4 × 4 gauze
- Skin cleanser
- Topical anesthetic
- Local anesthetic or nerve block (based on location and extent of injury)
- Normal saline for irrigation
- 35- to 50-mL syringe
- Splash guard or 16- to 18-gauge angiocatheter
- Surgical scrub
- Suture kit
- Suture material
- Skin tape
- Topical antibiotic

PROCEDURE

Laceration Involving the Vermilion Border

- Place the absorbable pad under the patient’s chin.
- Cleanse the area.
- Apply topical anesthetic.
- Perform anesthesia/block.
- While the anesthetic takes effect, prepare the other equipment.
- Cleanse the area and cover with a fenestrated sterile drape.
- Place deep suture as necessary.
- Approximate the vermilion border with the first suture using 6–0 nonabsorbable suture material.
- You can also approximate the vermilion border and place a mark with a pen of where you will put the first suture.
- Misalignment of as little as 1 mm can cause disfigurement.
- Once the border is aligned, continue closure using simple interrupted sutures.
- Apply topical antibiotic (**FIGURE 25.17**).

Intraoral Laceration

Any laceration that is gaping, greater than 2.0 cm, or has the potential for food particles to become entrapped should be sutured. The size and depth of the wound will determine how many layers of sutures will be required for closure. If there is a deep space, then internal suture(s) should be performed. Simple interrupted or continuous sutures can be used to close the surface layer with absorbable material.

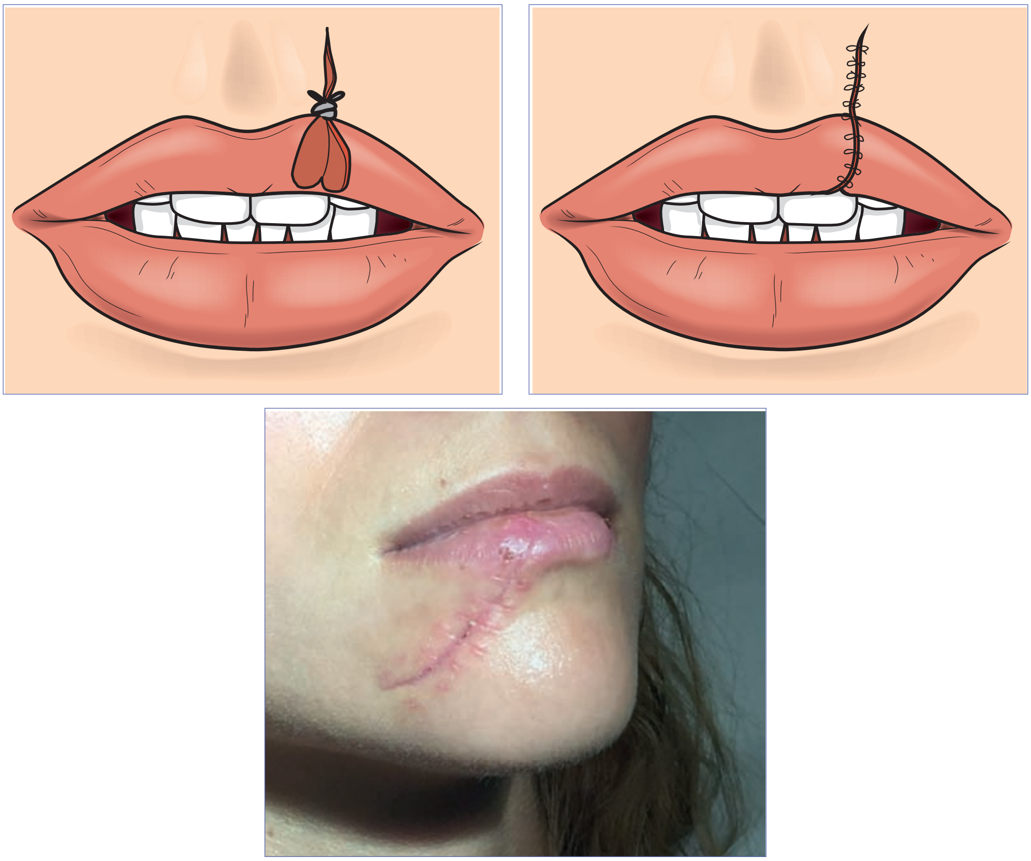


FIGURE 25.17 Closure of a lip laceration involving the vermilion border.

EAR LACERATION

SPECIAL CONSIDERATIONS

The ear is unique in that it contains vascular skin tissue covering avascular cartilage tissue. Proper repair of the injury most often results in a good outcome with regard to healing and cosmetic result. Any large avulsions or cartilage involvement should be referred immediately to a plastic surgeon for repair. When small areas of cartilage are involved, the area must be debrided and covered with skin for proper healing and outcome. This will decrease the chance of developing chondritis. The auricular cartilage making up the structure of the ear is avascular and depends on the blood supply from the perichondrium and surrounding skin tissue for oxygen supply and nutrients. Hence, it is imperative that such a violation of these two structures be remediated in terms of cartilage viability. A laceration involving the cartilage is seen in **FIGURE 25.18**. Most lacerations of the ear that involve only the skin layers should be closed using the aforementioned methods of closures based on the extent of the laceration. All avascular cartilage must be covered to prevent hematoma formation and promote healing. Local anesthesia must be avoided as it can distort important landmarks. Regional nerve blocks should be used as discussed in Chapter 20, Procedures for Performing Auricular Anesthesia. Closing a laceration to the pinna with exposed cartilage is discussed here.

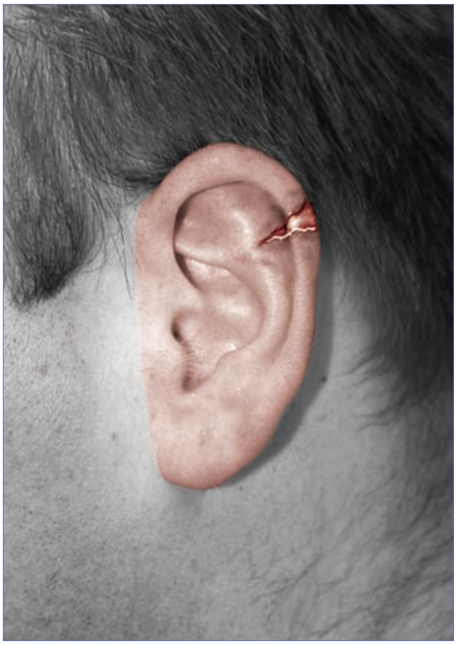


FIGURE 25.18 Photograph showing a wound to the pinna.

PROCEDURE PREPARATION

- Nonsterile gloves
- Absorbent pad
- 4 × 4 gauze
- Skin cleanser
- Topical anesthetic
- Local anesthetic or auricular block
- Normal saline for irrigation
- 35- to 65-mL syringe
- Splash guard or 16- to 18-gauge angiocatheter
- Surgical scrub
- Suture kit
- No. 15 scalpel
- Suture material
- Topical antibiotic

PROCEDURE

- Cleanse the area.
- Perform anesthetic block (see Chapter 20).
- While the anesthetic takes effect, prepare the other equipment.
- Cleanse the area and cover with a fenestrated sterile drape.
- With the scalpel, cut a full-thickness wedge (triangle) from the antihelix (**FIGURE 25.19A**).
- Excise the cartilage.
- Leave 1 mm of overhanging skin to ensure eversion during closure.
- Because cartilage is so friable and avascular, either do not suture or place sutures through the perichondrium only.
- With 6–0 nonabsorbable suture material, perform closure (**FIGURE 25.19B, C**).
- Apply a pressure dressing to prevent auricular hematoma.
- Close follow-up is required.

When closing percutaneous lacerations of the ear not involving the cartilage, close as you would other lacerations but begin posteriorly and end anteriorly. Vertical mattress sutures may be needed when repairing the helix of the ear to ensure eversion.

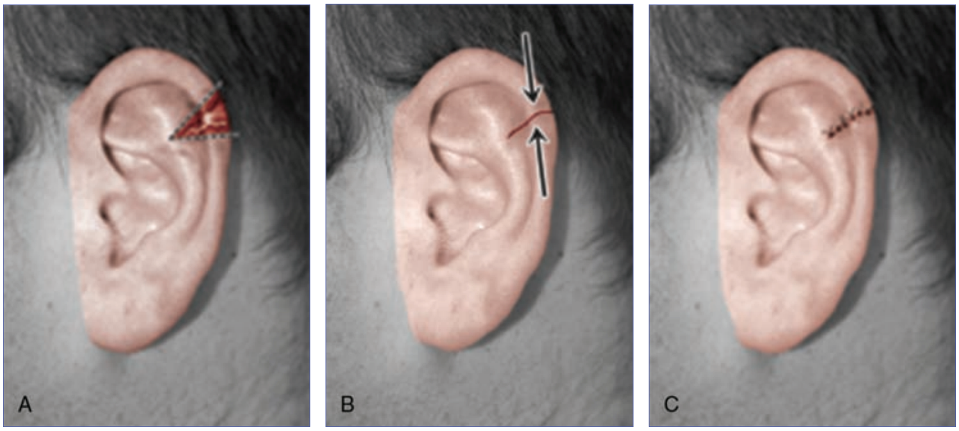


FIGURE 25.19 Wedge excision and repair of an ear laceration.

SKIN TEARS IN THE ELDERLY

SPECIAL CONSIDERATIONS

A skin tear is a wound caused by shear, friction, and/or blunt force resulting in a separation of skin layers. Older people with thin, frail skin are more vulnerable to this type of wound, which can be full thickness or partial thickness. These elderly patients often have significant comorbidities and may be on anticoagulants that challenge a practitioner's efforts at hemostasis. Often, skin tears in the elderly can be underappreciated, but these acute wounds are at high risk of becoming complex chronic wounds.

Timely assessment and management are important. Superficial, partial-thickness skin tears in which the edges can be realigned in the normal anatomical position and the flap color is not pale, dusky, or darkened can be repaired with tissue adhesive. Closure with suture is often not recommended. Deeper, full-thickness tears, however, may require sutures. In these cases, special strategies may be needed in order to approximate the wound edges without undue stretching. It is important to avoid a cheese-wire effect on the skin. Cheese-wire effect is a complication caused by the taut suture pulling through the thin tissue.

Skin tape can be used to bolster wound edges that require suture to approximate (**FIGURE 25.20**) so that tension-load bearing is done by the suture without the cheese-wire effect on the fragile skin. Principles of cleansing, debriding, and revising previously discussed apply here. In addition, dressings must be carefully selected, applied, and removed to avoid further trauma.

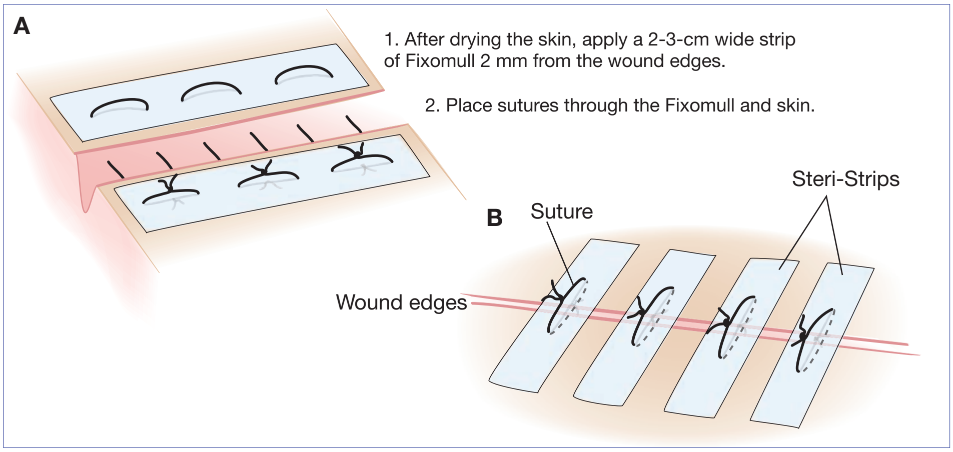

A
1. After drying the skin, apply a 2-3-cm wide strip of Fixomull 2 mm from the wound edges.
2. Place sutures through the Fixomull and skin.
B
Suture
Steri-Strips
Wound edges

FIGURE 25.20 Illustrations depicting use of skin tape with sutures.

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CHAPTER 26

Tendon Repair

David T. House

BACKGROUND

Tendons are load-bearing connective tissues composed mostly of water and parallel collagen fibers. Tendons attach to bony surfaces and act as pulleys that transfer force from muscle to bone, thereby enabling stability and musculoskeletal motion. Tendons, particularly those in the hands and feet, are classified based on their function. Extensor tendons are more flattened and promote extension of a digit or extremity, whereas flexor tendons are more round, enabling flexion. Patients present to the ED with tendon injuries that occur by various mechanisms, resulting in functional impairment. Injuries, such as hyperextension, blunt force, penetrating injuries, and puncture wounds, may result in partial or total tendon injury. Underlying bony injuries, such as avulsion fractures, may exist, and may provide indirect evidence of an occult tendon injury. Patients with partial tendon tears may experience tenderness, pain, and reduced strength at the site of injury. Symptoms, such as triggering, entrapment, or eventual rupture, may occur with partial tendon injuries. Typically, patients may report a "pop" or a "snap" sensation with a tendon rupture.

Flexor Tendon Injury

Flexor tendon injuries are typically less common than extensor tendon injuries and are more difficult to treat. Flexor tendons consist of both a synovial and fibrous sheath that keeps the tendon lubricated, thereby allowing stretching and smooth movement. Nerve injuries are often associated with flexor tendon injuries due to the proximity of the nerves to such flexor tendons. It is highly recommended that all flexor tendon lacerations be repaired by an experienced surgeon due to synovial sheath involvement and potential complications such as infection, specifically purulent flexor tenosyonovitis. In the ED, temporary stabilization may be performed followed by loose closure. Depending on the extent of injury, flexor tendons may undergo primary or delayed primary repair. Flexor tendon injuries of the hand are classified based on their location. A five-zone classification (**FIGURE 26.1**) exists, with zone II considered to be the "no-man's land." Zone II flexor tendon injuries must be repaired by a hand specialist due to the high risk of adhesions and complications. In general, once stabilization and closure are complete in the ED, definitive treatment by an experienced surgeon can take place as far out as 1 to 2 weeks.

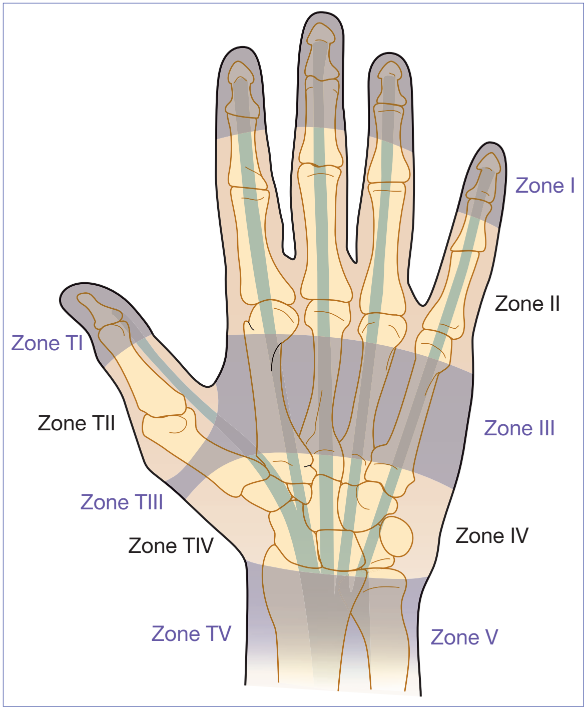

FIGURE 26.1 Zones of the hand. Note the relationships to the underlying structures.

Extensor Tendon Injury

Due to the superficial depth of extensor tendons and lack of fibrous tendon sheaths, extensor tendon injuries are more common than flexor tendon injuries. It is recommended that definitive extensor tendon repair occurs within 2 weeks of injury. Like flexor tendon injuries, it is highly recommended repair be performed by an experienced surgeon. If not properly repaired, patients with extensor tendon injuries may experience functional impairment. ED clinicians may repair extensor tendons if the ends of the tendon are easily visualized and well demarcated secondary to them not possessing a synovial sheath/synovial fluid and hence less potentially a source of infection. Urgent follow-up must occur within 1 to 3 days with an experienced surgeon. A separate zone classification system was developed for hand extensor injuries, zones I–VIII (**FIGURE 26.2**). Typically, extensor tendon injuries with less than 50% laceration do not require repair. If repair is necessary, extensor tendons may be repaired using a horizontal mattress, figure-of-eight, modified Bunnell, or modified Kessler suture technique. Zones I to V injuries may be repaired with a nonabsorbable 5-0 suture and zone V to VIII injuries repaired with 4-0 nonabsorbable sutures. Close follow-up with a specialist is recommended within 1 to 3 days.

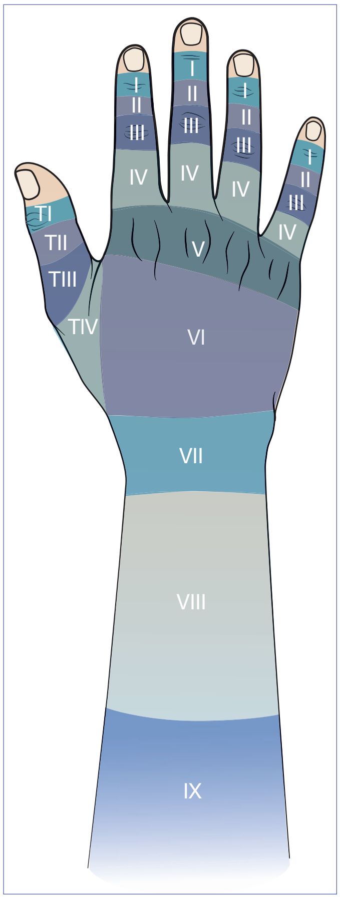

FIGURE 26.2 Dorsum of hand and forearm divided into anatomic zones.

PATIENT PRESENTATION

- Injury (open or closed wound)
- Pain
- Bleeding
- Deformity
- Decrease or loss of extension and/or flexion
- Decreased or loss of sensation

TREATMENT

Treatment of tendon injuries consists of first obtaining a history to include mechanism of injury, hand dominance, occupation, and tetanus immunization status. After the history, it is essential to perform a thorough physical examination of the injured area. In the case of a hand injury, examination of each distal interphalangeal (DIP) joint, proximal interphalangeal (PIP) joint, and metacarpophalangeal (MCP) joint against resistance must take place while assessing both the motor and neurovascular status of each. Always compare with the uninjured side. Plain radiographs should be obtained to evaluate for foreign bodies or underlying fractures. In addition, bedside ultrasound may be used to identify tendon injury or hidden foreign bodies. Prior to exploring open wounds, the area should be anesthetized using local infiltration or a digital or a regional block. Once anesthesia is obtained the area should be prepped, followed by wound exploration, extensive irrigation with pressure, and debridement. Exposed tendon should be visualized through full range of motion to ensure that injured tendon is not hidden proximal or distal to the surface wound. It is imperative that in regards to proper visualization, hemostasis must be maximized; the use of a finger tourniquet should be utilized. The type and method of tendon repair and closure will depend on the location and the extent of injury as the injury may have occurred in an extended or flexed position. It is important to clearly identify the ends of the tendon and handle carefully to prevent further trauma to the tendon. Extensive instrumentation can lead to adhesion formation. A single suture may hold a retracted tendon in place. Debride tendon ends if irregular or dirty using a No. 11 blade scalpel taking care not to remove too much length. Specific procedures will be discussed further in this chapter. Once skin closure has been completed, an antibacterial dressing and splint should be placed. Consider an intravenous (IV) dose of antibiotics and prescribe prophylactic antibiotics. Close follow-up should be arranged with a hand specialist in 1 to 3 days.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Flexor tendon injury
- Lack of appropriate training
- Extensive soft tissue damage (crush injury), tissue loss, or edema
- Multiple tendon lacerations
- Gross wound contamination
- Underlying joint and/or bony abnormality (fracture)
- Human or animal bite
- Overlying infection

SPECIAL CONSIDERATIONS

- Primary versus delayed primary repair based on presenting injury and recommendation from specialist
- Concomitant nerve or vascular injury
- Extensive wound contamination
- Immunosuppression

PROCEDURE PREPARATION

Equipment

ANESTHESIA (DIGITAL, HAND, OR EXTREMITY)

- Nonsterile gloves
- Chlorhexidine or povidone-iodine solution
- 10-mL syringe
- 25- to 27-gauge needle, 1½ to 2 inches long
- 16- to 18-gauge needle
- Anesthetic solution (without epinephrine for digital block)

WOUND IRRIGATION AND PREPARATION

- Personal protective equipment
- Sterile saline or Ringer's lactate solution (at least 500 mL)
- Irrigation set or splash guard
- Syringe 30 to 60 mL
- 16- to 18-gauge angiocatheter
- IV tubing

TENDON AND SKIN REPAIR

- Sterile gloves
- Sterile surgical towels
- 4 × 4 gauze squares
- Sterile suture kit (needle driver, forceps, suture scissors, and basin)
- No. 11 blade disposable scalpel
- Nonabsorbable, synthetic, and braided suture (3–0, 4–0, 5–0)
- Nylon suture for skin closure (4–0 or 5–0)

WOUND DRESSING AND SPLINT

- Topical antibiotic ointment
- Nonadherent gauze or Xeroform
- Elastic bandage
- Splinting materials

PROCEDURE

Flexor Tendon

- Put on nonsterile gloves.
- Cleanse the skin with chlorhexidine or povidone-iodine solution.
- Perform local, digital, or regional block based on injury location.
- Open your suture kit and place all necessary equipment onto a sterile field.
- Put on sterile gloves.
- Once anesthesia is again achieved, extensively irrigate the wound with 8 to 12 psi using a 30- to 60-mL syringe with a splash guard or 16- to 18-gauge angiocatheter.
- Cover the wound with a sterile fenestrated drape.
- Perform further exploration and conduct wound debridement.
- Perform skin closure using a simple interrupted suture technique with nonabsorbable sutures.
- Splint and immobilize injury based on the location of injury.
- Administer antibiotics and tetanus prophylaxis.
- Establish referral to specialist within 1 to 3 days prior to patient discharge.

Extensor Tendon

- Put on nonsterile gloves.
- Cleanse the skin with chlorhexidine or povidone-iodine solution.
- Perform local, digital, or regional block based on injury location.
- Open your suture kit and place all necessary equipment onto a sterile field.
- Put on sterile gloves.
- Once anesthesia is again achieved, extensively irrigate the wound with 8 to 12 psi using a 30- to 60-mL syringe with a splash guard or 16- to 18-gauge angiocatheter.
- Cover the wound with a sterile fenestrated drape.
- Perform further exploration and conduct wound debridement as necessary.
- Perform open wound closure using a simple interrupted suture technique with nonabsorbable sutures.
- Splint and immobilize injury based on the location of injury.
- Administer antibiotics and tetanus prophylaxis.
- Establish referral to specialist within 1 to 3 days prior to patient discharge.

Suture Techniques

There are four suturing techniques effective in extensor tendon repair. For extremely thin tendons, the horizontal mattress and figure-of-eight are appropriate. The modified Kessler and Bunnell stitch are more effective and provide greater strength for thicker, core-type tendons.

HORIZONTAL MATTRESS

- Insert the needle perpendicular into the tendon (about 4–8 mm from the tendon edge).
- Pass the needle through to the opposite tendon edge and exit.
- Place the needle backward in the needle driver and insert into the tendon (about 4–8 mm) farther down the edge (the edge where the needle has just been passed through) and pass from the far side of the wound back to the near side.
- The needle should exit the tendon about 4 to 8 mm below the original wound edge from the original insertion site.
- Tie the suture gently on the side of the wound where the suturing began.
- Repeat as necessary to cover the entire lacerated area of the tendon (**FIGURE 26.3**).

FIGURE-OF-EIGHT

- Starting on one side of the tendon, insert the needle perpendicularly through the full thickness of the tendon on that side, then finish the first half of the stitch by going from bottom to top on the opposite-side tendon (similar to a simple interrupted suture).

- Advance back to the opposite side of the tendon (the needle should now be back on top) and enter the tendon perpendicularly (going from top to bottom).
- Go through the full thickness of the tendon and come out on the opposite side from the undersurface of the tendon.
- Tie the suture gently on the side of the wound where the suturing began.
- Repeat as necessary to cover the entire lacerated area of the tendon (**FIGURE 26.4**).

MODIFIED BUNNELL

- Enter the tendon end on the radial half and at approximately one third of the diameter of the tendon.
- Pass the needle diagonally through the tendon and exit on the ulnar side.
- Wrap the suture around the tendon and reenter the tendon on its dorsal half.
- Pass the needle directly through the tendon to exit the dorsal surface of the radial aspect of the tendon.
- Enter the radial side of the tendon and cross the suture diagonally through the tendon to exit its ulnar end. The needle must exit through the ulnar one third of the tendon end.

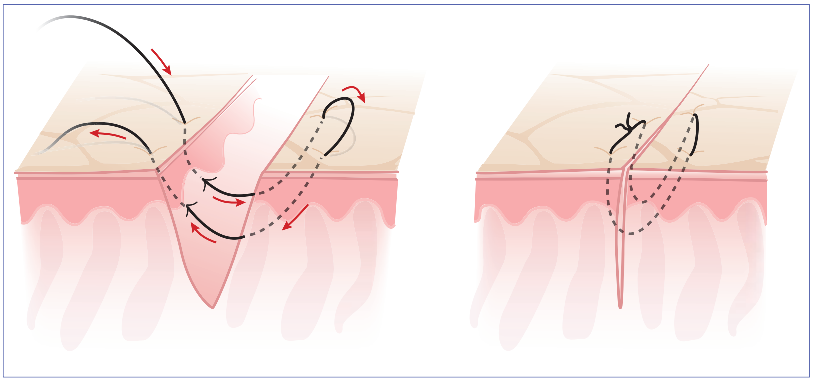

FIGURE 26.3 Horizontal mattress suture.

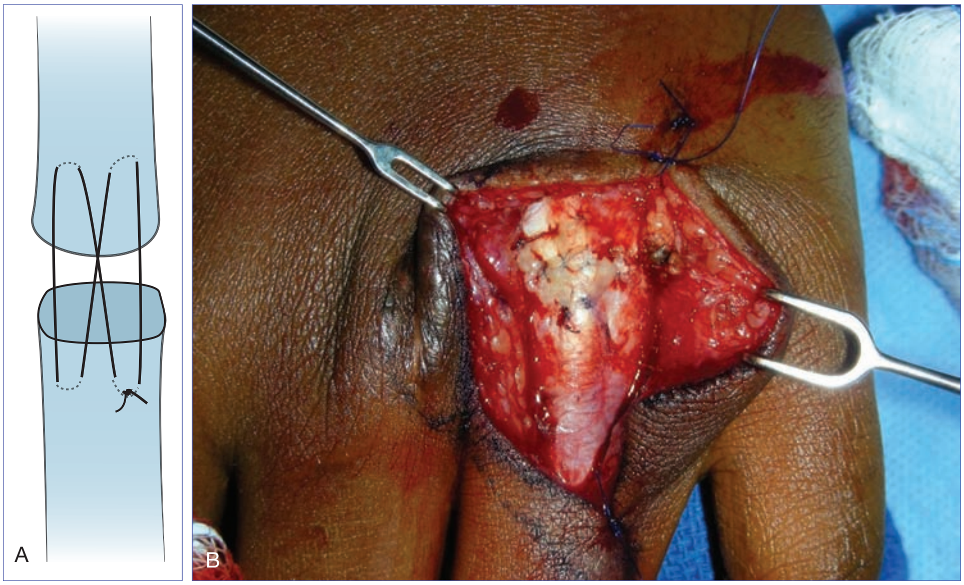

FIGURE 26.4 **(A)** Figure-of-eight technique; **(B)** primary closure of finger extensor tendon laceration with the figure-of-eight technique.

Source: (A) Courtesy of Theresa Campo. (B) Henry, G. I. (2020). Extensor tendon lacerations. In J. A. Molnar (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/1286225-overview

- Repeat the same stitch on the opposing piece of the tendon.
- The two free ends of the suture should be on the radial side of the tendon.
- Approximate the ends by pulling gently, making sure to avoid applying force so that the tendon ends bunch up.
- Secure the stitch with a knot (**FIGURE 26.5**).

MODIFIED KESSLER

- Introduce the needle perpendicularly into the tendon on the ulnar or radial side. For this procedure, start on the ulnar side.
- Pass the suture through the length of the tendon and exit dorsally.
- Wrap the suture around the tendon and reenter the ulnar side perpendicularly and 1 to 2 mm closer to the tendon end.
- Pull the suture through to exit the tendon on the radial side.
- Wrap the suture around the tendon and enter the dorsal aspect on the radial half of the tendon. This entrance stitch must line up with the first dorsal stitch.
- Pass the needle through the length of the tendon to exit the end of the tendon on the radial one third of the tendon.
- Repeat the same stitch on the opposing piece of the tendon.
- The two free ends of the suture should be on the radial side of the tendon.
- Approximate the ends by pulling gently, making sure to avoid applying force so that the tendon ends bunch up.
- Secure the stitch with a knot (**FIGURE 26.5**).

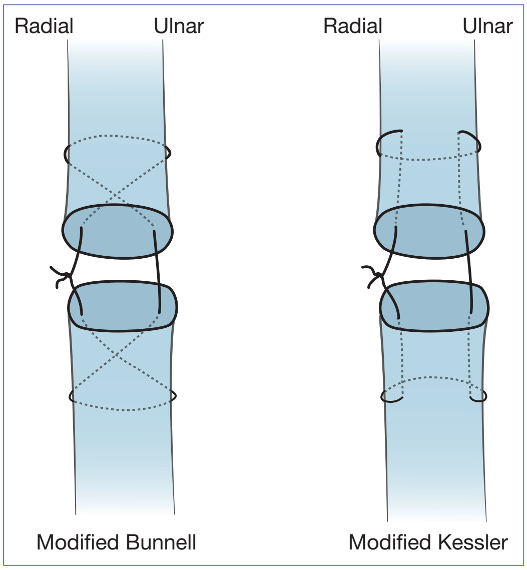

FIGURE 26.5 Bunnell and Kessler suture techniques for tendon repair.

ULTRASOUND GUIDANCE

Bedside ultrasonography is a quick and useful diagnostic tool used to evaluate potential tendon injuries. In the clinical setting, ultrasound use can assist in identifying partial to total tendon injuries. The sensitivity (100%) and specificity (95%) of bedside ultrasound use in identifying tendon lacerations is greater than traditional wound exploration or MRI. It is important to note that on physical exam, normal tendon function may be intact even though an underlying partial tendon injury (up to 90% of tendon width) has occurred. In addition, ultrasound is a useful, noninvasive, painless tool that can be used to get a more thorough exam due to pain, edema, underlying fractures, foreign bodies, or lack of patient cooperation. To visualize extensor or flexor tendons, a linear array transducer is used in parallel with the tendons. The tendon will appear hyperechoic (bright white) in relation to the surrounding tissue with the probe parallel to the longitudinal axis of the tendon fibers (**FIGURE 26.6**). For better visualization the use of a liquid interface (such as water) or a standoff pad is helpful.

POSTPROCEDURE CONSIDERATIONS

Prophylaxis for human fight/bite and animal bites:

- Antibiotic prophylaxis to cover for skin flora.
  - Amoxicillin–clavulanate, 875/125 mg (25–30 mg/kg/d) orally BID for 3 to 5 days or until follow-up
  - Clindamycin (for penicillin allergies), 300 mg (8-12 mg/kg/d) TID **plus**
    - Trimethoprim–sulfamethoxazole double strength (8–10 mg/kg/d) BID **or**
    - Doxycycline, 100 mg BID **or**
    - Ciprofloxacin 500 mg (10–20 mg/kg/d) BID (use alternatives in children)
- Administer tetanus prophylaxis if immunization is not up to date.

Bleeding

- It is common to have postprocedure bleeding.
- Apply direct pressure and elevate the extremity.

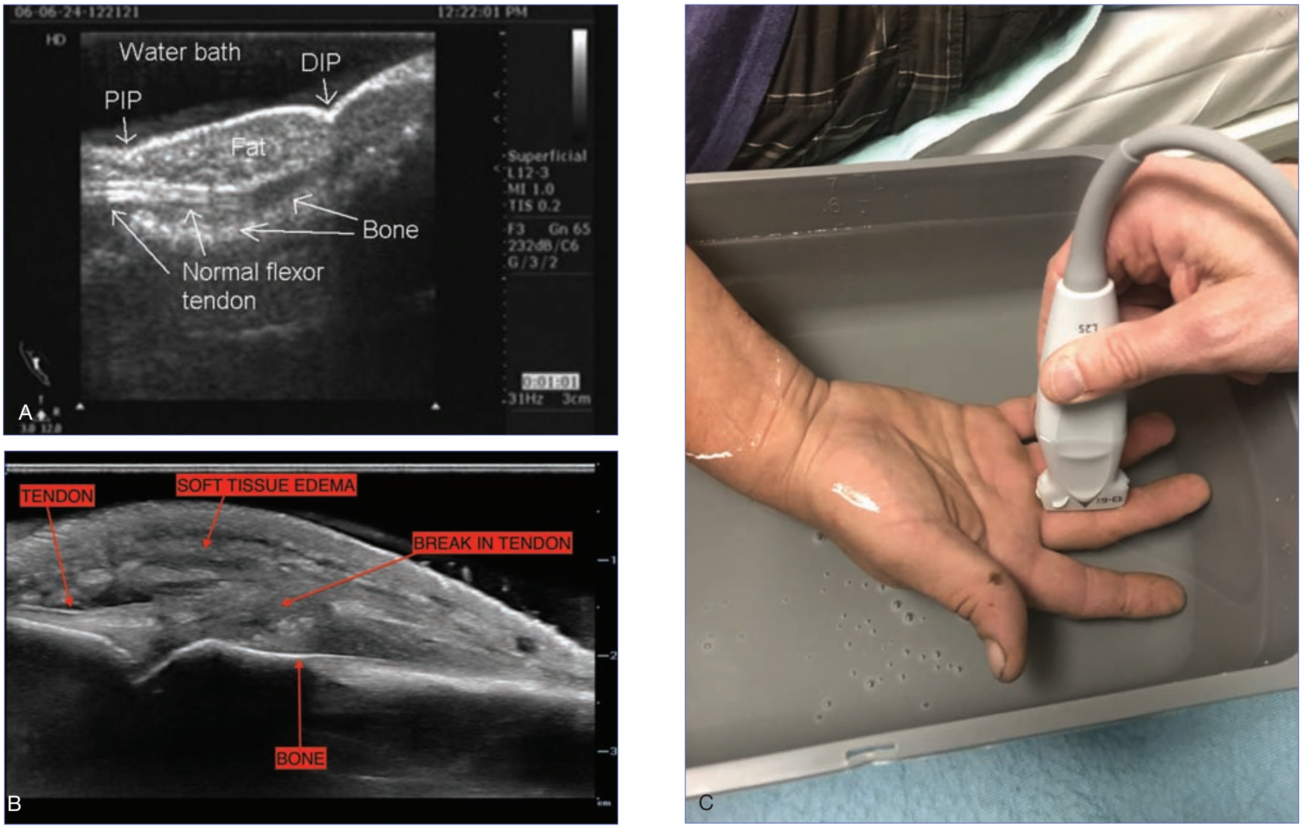

FIGURE 26.6 (A) This image shows an ultrasound of the flexor tendon of a finger with the structures labeled. It was performed using a water bath with the water as the conduction agent. For comparison, see the abnormal ultrasound image that displays a tendon violation. (B) A tendon laceration. (C) Image shows a water bath ultrasound technique

DIP, distal interphalangeal; PIP, proximal interphalangeal.

Source: (A) Image courtesy of Dr. Christopher Moore and Dr. Michael Osborne.

Pain

- Postrepair pain is common; however, elevation, splinting, and immobilization will help relieve pain.
- If necessary, pain medication may be prescribed.

EDUCATIONAL POINTS

Assessment

- Knowledge of anatomy is essential.
- Recognize injury early and actively exclude tendon injuries.
- Provide a thorough physical exam (complete with motor and sensory evaluation) with bedside ultrasonography (if available).
- Use radiological studies to identify concurrent injuries such as fractures and foreign bodies.
- Thorough exploration of open wounds is necessary.
- The sensitivity (100%) and specificity (95%) of bedside ultrasound use in identifying tendon lacerations is greater than traditional wound exploration or MRI.
- Realize that a partial tendon injury may exist with up to a 90% violation; if clinical suspicion is high, make every attempt to evaluate the tendon.

Treatment

- Extensive irrigation and debridement
- Splinting in functional alignment
- Prophylactic antibiotics

Follow-Up

- Contact a specialist to arrange follow-up prior to discharge.
- Educate the patient.
- Close follow-up and referral for rehabilitation with hand specialist are needed.

COMPLICATIONS

- Infection
- Compartment syndrome
- Adhesion formation
- Rupture of repair
- Swan neck and/or boutonniere deformity of digits

PEARLS

- One cannot examine nor repair what one cannot see; the use of a finger tourniquet is critical in regards to both.
- Early consultation and intervention are preferred and will improve patient outcomes.
- Tendon laceration repair is a high-risk procedure due to infection and loss of functioning.
- Always examine the tendon in a full range of motion as the anatomical position of the finger/hand may have been in a flexed or extended position at the time of injury.
- Always consult a hand or orthopedic surgeon prior to intervention and discharge.
- Educate the patient as to the risks prior to performing tendon repair and present options.
- When applying a splint, check neurovascular status distal to injury prior to discharge.
- Use ultrasound in a bath solution and practice often in order to appreciate the normal appearance of tendons.
- Arrange immediate follow-up (1–3 days) with a hand or orthopedic specialist and give information to the patient.

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CHAPTER 27

Managing Minor Burns

Theresa M. Campo and Kristopher Maday

BACKGROUND

Burns are defined as acute, traumatic injuries to the skin or surrounding tissues caused by thermal, chemical, or electrical exposures. This chapter outlines the type, degree, and treatment of minor burns, including sunburn. Acute management of any burn is to immediately stop the burn from causing further damage, initiate prompt treatment, and arrange referral as necessary. Always assess for the potential of severe associated injuries such as inhalation injuries, cardiac dysrhythmias, ocular damage from electrical injuries, and compartment syndrome on circumferential extremity burns. Follow-up is imperative with burns to reduce the risk of infection, scarring, and loss of function.

Traditionally, burns were classified into three categories: first, second, or third degree. Today, burns are classified by the depth and extent of the burn. The current classifications are *superficial* (or epidermal), *partial thickness* (superficial or deep), and *full thickness*. The current classifications correspond with the traditional categorization. When determining the depth of thermal injuries for classification, there are several important considerations to remember. First, these injuries are often not uniform in depth and may have different degrees of damage within the same zone of injury. Second, thermal injuries are dynamic wounds and can progress to deeper injuries in the first several hours of assessment and treatment. Third, specific areas of the body are also susceptible to deeper injuries despite their superficial appearance. These areas are the volar surfaces of the forearms, ears, perineum, and medial thighs, as well as the thin skin of children under the age of 5 and adults over the age of 55.

Superficial burns, or first-degree burns, involve the epidermal layer only and are painful, red, and dry. Blistering does not occur and the damaged area will blanch with pressure. Pain and erythema typically subside with 72 hours of injury and are completely healed without scarring within 7 days. The most common superficial burn is sunburn. Partial-thickness burns can be either superficial or deep. Superficial partial-thickness burns involve the epidermal layer and several dermal layers of the skin and classically form blisters between these layers within 24 hours of injury. They are painful, red, weeping, and blanch with pressure. Superficial, partial-thickness burns generally heal within 7 to 21 days with possible skin pigmentation changes, but minimal scarring or functional limitation. Healing time varies due to the exudative fluid from the wound creating an ideal environment for bacterial colonization resulting in delayed wound healing. Deep partial-thickness burns involve the epidermal and dermal layers and may damage hair follicles and glandular tissue. They are not as painful as epidermal or superficial partial-thickness burns because of the loss of sensory nerves and do not blanch with pressure. Sensation to pinpricks and deep pressure is intact. As long as proper wound management prevents infection, these burns can heal without grafting within 9 weeks, but often are associated with hypertrophic scarring. If deep, partial-thickness burns involve a joint or skin-fold space, functional limitations and decreased range of motion may result. Deep partial-thickness burns may be difficult to distinguish from full-thickness burns during the initial evaluation.

Full-thickness burns involve the entire epidermal and dermal layers of the skin and often injure the subcutaneous tissues and structures. They are dry, leathery, and completely insensate with patients often presenting with little to no pain. The color of the burn can be waxy-white, leathery-gray, or brown/black in appearance and wounds have a burn eschar overlying the injured area, which must be excised for proper wound healing. These burns cause significant scarring, loss of function, and usually require skin grafting. The depth of a burn and total body surface area (TBSA) involved have a direct impact on healing and mortality. The easiest estimation of burn TBSA can be done using the "rule of nines," which designates a percentage to various anatomical locations. In adults, the head and each arm account for 9% each; the genitals equal 1%; and the anterior, posterior trunk, and each leg account for 18% each. The percentages for using the rule of nines in children are adjusted to reflect proportional differences (**FIGURE 27.1**).

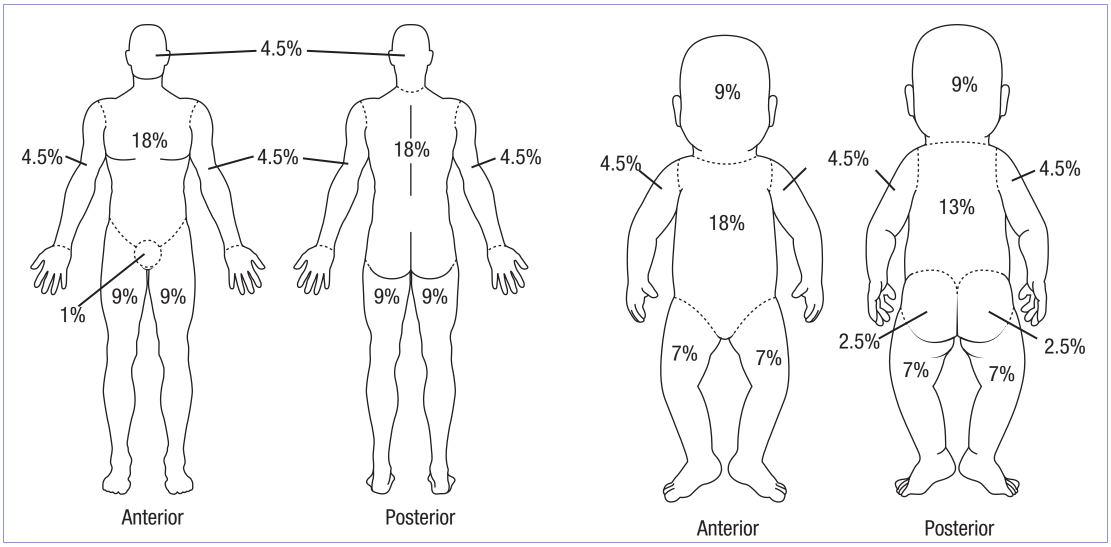


FIGURE 27.1 Rules of nines.

A more practical way to estimate the percentage of TBSA burned is to use the palm of the patient's hand, which equals 1%. This is a practical and accurate way to estimate the TBSA without using calculations and diagrams (**FIGURE 27.2**).

The most accurate means of estimating injured TBSA is use of the Lund and Browder diagram (**FIGURE 27.3**). This classification can be used on both adults and children and takes into account the growing child and changes in the proportions of a child's body in regard to TBSA. This chart also further documents areas of partial- versus full-thickness injuries to observe for potential injury progression over the initial time-management period. The Lund and Browder diagram is more commonly used by tertiary burn centers and reserved for larger or more significant thermal injuries requiring transfers to these centers.

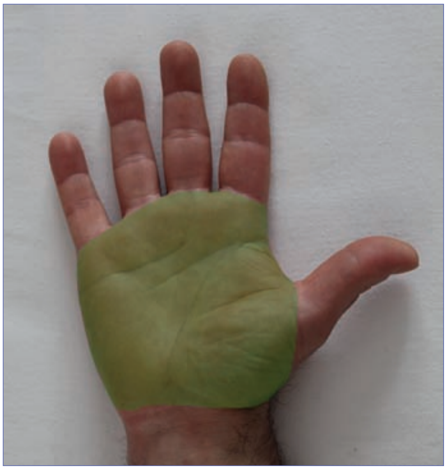


FIGURE 27.2 The palm of the hand equals 1% of total body surface area.

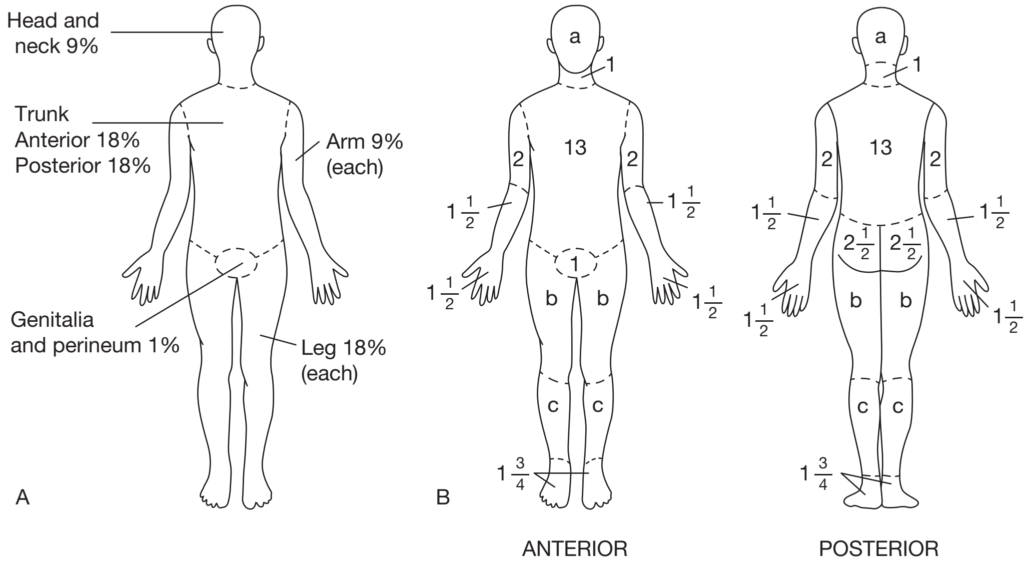
Classification as a Minor Burn

The American Burn Association has a list of criteria that must be met for a thermal injury to be considered minor. Injuries must be one of the following:

- Partial-thickness burns <10% TBSA in patients 10 to 50 years old
- Partial-thickness burns <5% TBSA in patients under 10 or over 50 years old
- Full-thickness burns <2% TBSA in any patient without other injury

If the injury includes one of the injuries listed, ALL of the following must also be met for the injuries to be considered minor:

- No other associated injury (inhalation or high-voltage injury)
- Does NOT involve the face, hands, perineum, or feet
- Does NOT cross major joints
- Is NOT circumferential


Head and neck 9%
Trunk Anterior 18% Posterior 18%
Arm 9% (each)
Genitalia and perineum 1%
Leg 18% (each)
A
B
a
1
13
2
2
1 1/2
1
b
b
c
c
1 3/4
2 1/2
ANTERIOR
POSTERIOR

Relative percentage of body surface areas (%BSA) affected by growth

	0 *yr*	1 *yr*	5 *yr*	10 *yr*	15 *yr*
a — ½ of head	9½	8½	6½	5½	4½
b — ½ of 1 thigh	2¾	3¼	4	4¼	4½
c — ½ of 1 lower leg	2½	2½	2¾	3	2¼

FIGURE 27.3 Diagram for estimating percent age of total body surface area in adults and children affected by burns. (A) Rule of "nines"; (B) Lund and Browder diagram for estimating extent of burns.

Source: U.S. Department of Health and Human Services.

PATIENT PRESENTATION

Epidermal

- Painful
- Red
- Dry
- No blisters

Superficial Partial Thickness

- Very painful
- Red
- Blanches with pressure
- Moist
- Weeping
- Blister may or may not be present (usually intact if present)

Deep Partial Thickness

- Pain
- Perception of pressure
- Waxy appearance

Full Thickness

- Charred/leathery appearance
- Perception of deep pressure
- Waxy-white or gray color
- Absence of sensation in deepest burn areas

TREATMENT

Treatment is based on depth, cause, and BSA affected. The goal of treatment is to quickly stop the burn, identify the extent of the burn, and administer pain medication immediately. Cooling a minor burn can be effective for up to 3 hours after the initial injury and is best achieved with a moist cool towel. Ice water immersion is not recommended as it can lead to further injury secondary to vasoconstriction and hypothermic injury. In addition, cooling should only be used in patients with a minor burn; cooling larger areas can lead to systemic hypothermia and coagulopathies. Application of silver sulfadiazine or topical antibiotic cream or ointment is utilized for burns with blisters or open wounds. Silver sulfadiazine should not be used on the face.

Burns that require hospitalization and/or referral to a burn center are listed in the next section.

Burn Center Referral Criteria

- Partial-thickness burns >10% TBSA
- Burns involving the face, hands, feet, genitalia, perineum, or major joints
- Full-thickness burns in any age group
- Electrical burns, including lightning injury
- Chemical burns
- Inhalation injury
- Burns in any patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
- Any patient with burns and concomitant trauma
- Burned children in hospitals without qualified personnel or equipment for the care of children
- Burn injury in patient who will require special social, emotional, or rehabilitative intervention

SPECIAL CONSIDERATIONS

- Diabetes
- Immunosuppression
- Chemotherapeutics
- Anticoagulation

PROCEDURE PREPARATION

- Sterile water or normal saline for irrigating
- Nonadherent gauze
- 2 × 2 or 4 × 4 gauze (depending on area)
- Loose roll gauze (Kerlix)
- Tape

PROCEDURE

- Medicate for pain.
    - Partial- and full-thickness burns usually require either oral or parenteral administration of opioid pain medication.
- Cleanse the area with sterile saline to remove any products applied prior to arrival. Do not use povidone–iodine, chlorhexidine, or other cleaning solutions.
- Dry completely.
- Debride the area of any loose tissue.
- Cover with nonadherent gauze.
- Place 2 × 2 or 4 × 4 gauze over the nonadherent gauze.
- Loosely wrap the rolled gauze over the area.
- Assess perfusion to areas distal to dressing to ensure adequate blood flow during postinjury period.

POSTPROCEDURE CONSIDERATIONS

- Pain medication should be prescribed.
- Close follow-up with the burn center, plastic surgeon, or primary care provider is required.
- All patients with partial-thickness injuries or more should be given tetanus prophylaxis.

EDUCATIONAL POINTS

- Dressings should be changed at least once daily and optimally twice daily to evaluate for potential infection or perfusion deficits.
- Elevation will assist with reducing swelling.

COMPLICATIONS

- Infection
- Contracture
- Scarring

PEARLS

- Educate the patient to completely wash off the silver sulfadiazine before the next application. This medication has the potential to pigment the skin, prompting recommendations to avoid use on the face.
- Circumferential burns of the hands, feet, or body in children should be suspected for child abuse. Burns that spare flexor creases should also raise concern for nonaccidental trauma.
- Superficial/epidermal injuries do NOT need dressings or topical antimicrobials and pain control can be achieved with aloe vera and topical nonsteroidal anti-inflammatory agents only.
- Empiric antibiotic therapy is not appropriate.

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UNIT
VIII

Procedures for the Management of Nail and Nail Bed Injuries

CHAPTER 28

Procedures for Managing Ingrown Toenails

Clare Roepke

BACKGROUND

To understand how to remove an ingrown toenail, we should first touch on some basic toenail anatomy. The toenail is secured into the toe on three sides: by the proximal nail fold and by two lateral nail folds. The proximal nail fold covers the base of the nail and protects the nail matrix, which lies underneath. The cuticle (also called the *eponychium*) is formed from the proximal nail fold, attaches to the nail plate, and acts as a protector against microorganisms. The nail plate extends to the hyponychium (thick skin just underneath the distal nail plate). The nail bed facilitates the smooth movement of the nail plate distally, but does not participate in the actual nail development. It supports the nail and contains blood vessels and nerves. The nail matrix (root) is solely responsible for the formation and growth of the nail plate (**FIGURES 28.1** and **28.2**). Nails grow about 1 mm in a month.

Normal nail growth is distal from the proximal nail fold and should be smooth. However, lateral growth of the nail plate into the soft tissue causes an inflammatory response. Ingrown toenails are most often the result of improperly fitting shoes and improper nail cutting, but can be due to other conditions such as increased age, pregnancy, repetitive trauma, or poor hygiene. The shape of nail growth can also place a person at risk for developing infected ingrown nails. For example, many people think that cutting the nail in a round fashion, to mimic the shape of the toe, will avoid ingrowth into the lateral nail folds. This is incorrect. The correct way to cut the nail is actually straight across the top, preventing nail growth into the lateral folds. As you would imagine, the most common site for ingrowth is the great toe.

The severity of the ingrown nail and reaction to this form of growth can range from mild to severe. A mild presentation may consist of swelling, edema, and hyperkeratosis, whereas a moderate presentation may consist of increased edema, drainage, pain, and ulceration of the nail fold. Severe cases progress to increased production of granulation tissue with layering over the nail plate. This may be accompanied by infection and severe pain.

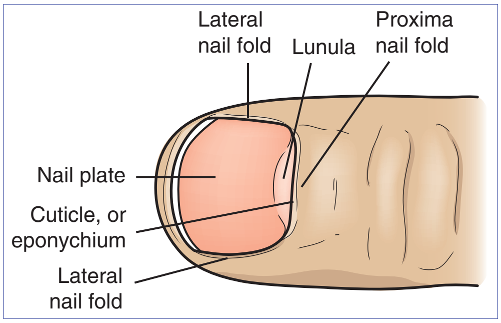

FIGURE 28.1 Anatomy of a toenail.

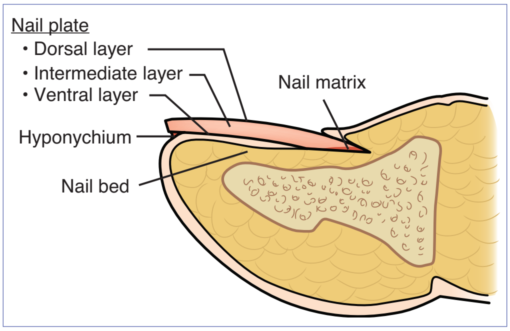

FIGURE 28.2 Lateral view of anatomy of a toenail.

PATIENT PRESENTATION

Patients usually present with pain, erythema, and edema of one or both of the lateral nail folds.

TREATMENT

Treatment is based on the severity of the ingrown toenail. The goal of treatment is to decrease pain and inflammation as well as to promote normal nail growth.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Allergy to local anesthetics
- Bleeding dyscrasia

SPECIAL CONSIDERATIONS

- Diabetics
- Immunocompromised patients

PROCEDURE PREPARATION

Minor Ingrown Toenail (Removal of the Spicule Only)

- Gloves (nonsterile)
- English Anvil Nail Splitter or sharp-pointed nail scissors (cautery is another option)
- Hemostat or forceps
- Antibiotic ointment
- Nonadhesive dressing
- Hard-sole shoe (if patient presents in a constricting shoe)

Moderate to Severe Ingrown Toenail (Removal of Spicule, Part of Nail, or the Entire Nail)

- Gloves (nonsterile)
- Tourniquet (optional)
- English Anvil Nail Splitter or sharp-pointed nail scissors
- Hemostat or forceps
- Normal saline
- Antibiotic ointment
- 10-mL syringe with small-gauge needle (27 gauge) filled with lidocaine or bupivacaine
- Nonadhesive dressing
- Hard-sole shoe (if patient presents in a constricting shoe)

PROCEDURE

Minor Ingrown Toenail

A minor ingrown toenail involves the spicule of the nail only. Inflammation, pain, and deformity are minimal. Only the distal nail is involved and removal is usually curative.

- Remove an oblique segment of nail, usually one-half or one-third of the way to the proximal nail fold, with either an English Anvil Nail Splitter (not usually available to you in the ED) or a sharp-pointed scissors (iris scissors are usually available and can be often pulled from a laceration tray; **FIGURE 28.3**). The preference for the English Anvil Nail Splitter is that this tool does a good job of cutting the nail while minimizing trauma to the underlying nail bed and matrix. This can be done with the sharp-pointed nail scissors as well, but care has to be taken to preserve the nail bed and matrix by applying upward pressure while cutting. Cautery is a last resort (if the other two options are unavailable) and can be more easily accomplished after soaking the toe in warm soapy water.

- After cutting the spicule, grasp the free part of the nail with your forceps or hemostat (using what you have available) and remove it from the toe. Granulation tissue and debris at the site may make removal challenging; so take care to go slowly and pull gently so as not to disrupt the nail bed and matrix, which can bleed easily.
- Once this is done, apply (liberally) a topical antibiotic ointment and cover with a nonadhesive dressing (you do not want your dressing to stick to the nail bed or matrix when the dressing is removed).

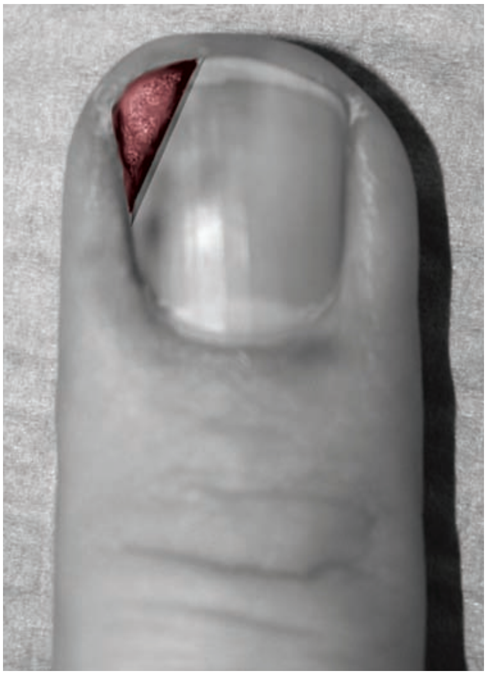

FIGURE 28.3 Image showing removal of the oblique section of the nail.

Moderate to Severe Ingrown Toenail

A moderate to severe ingrown toenail involves not only the spicule of the nail, but a part of the nail or the entire nail. How do you know whether you need to remove part of the nail or the whole nail? The easiest way is to see whether one or both of the lateral nail folds are involved. If only one nail fold is involved, partial nail removal is usually sufficient. If both nail folds are involved, you will likely be removing the entire nail (**FIGURE 28.4**).

Many sources suggest that treatment of moderate to severe ingrown toenail removal involves not only nail removal but also destruction of the underlying nail matrix to prevent regrowth. Although this may be indicated, this is not something that is usually done in the ED, as the required chemicals are not routinely in stock. As such, this chapter will not focus on this management and this procedure should be deferred to podiatry.

- Perform a digital block on the affected toe to provide comfort during the procedure.
- Consider the use of a tourniquet to create a bloodless field. You may use the cut finger of a glove (rolled up) or an actual tourniquet.
- Hold the toe steady and use your scissors to separate the lateral third of the nail from the nail bed. Slowly advance, separating your scissors parallel to the nail.
- Cut the nail lengthwise toward the cuticle. You may use you English Anvil Nail cutter (preferred) or a scissor, advancing until you are past the cuticle (the proximal nail fold).
- Grasp the cut part of the nail with your hemostat or forceps and twist it toward the remaining nail. Doing this effectively pulls the nail root out from under the cuticle.
- Remove the tourniquet. Apply pressure (gently) to stop any bleeding, irrigate the nail bed, and dry it.
- Apply antibiotic ointment (liberally) and then cover with a nonadhesive dressing.

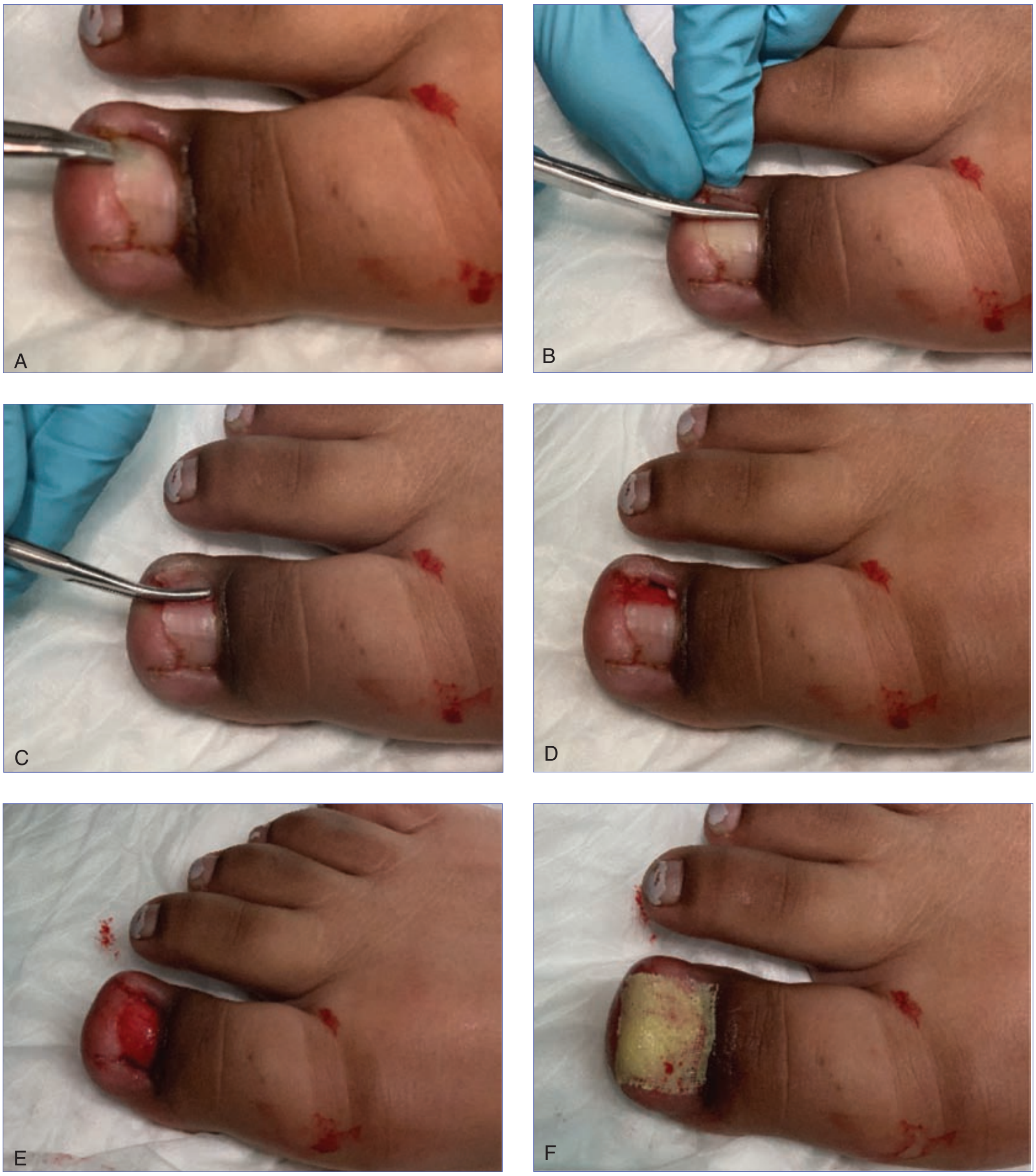

FIGURE 28.4 Photographs depict a partial nail-removal procedure.
(A) Separate nail from nail bed with scissors. (B) Cut the nail lengthwise toward cuticle. (C) Grasp nail with hemostat and twist. (D) Partial nail removed successfully. (E) Repeat steps until full nail is removed. (F) Apply antibiotic ointment and cover.

Source: Courtesy of Clare Roepke.

POSTPROCEDURE CONSIDERATIONS

When you are done, remember to remove the tourniquet (if used) and dress the wound. Use of a nonadhesive dressing is best so that it will not stick to the nail bed or matrix when it is changed. Remember to provide a less-constricting shoe (if available, like a hard-sole shoe). Make sure to provide guidelines on how to continue caring for the toe at home. These instructions should include soaks (two to three times a day in warm water, changing to a clean dressing every time), and a recheck in 48 to 72 hours to assess clinical improvement. Make sure to set expectations for time to healing, as improvement may take up to 2 to 4 weeks, and explain that complications can occur (infection, abnormal regrowth of nail, delayed healing). Podiatry follow-up is always recommended in these cases. Educate patients that the majority of these cases do NOT require systemic antibiotics.

EDUCATIONAL POINTS

- When approaching management of an ingrown toenail, evaluate to determine which part of the nail is involved. If the ingrown nail involves both lateral nail folds, set up for complete nail removal. If the involved nail involves only the spicule or one lateral nail fold, a simple or partial nail removal may suffice.
- Remember to have all tools bedside, to apply antibiotic ointment and a nonadhesive dressing, to dress the wound and provide a less-constricting shoe if possible.
- Set your patient up for success at home (expectations for time to healing, education on possible adverse outcomes, and instructions on when to follow up with podiatry, if needed).

COMPLICATIONS

- Complications include infection, abnormal regrowth of the nail, and delayed healing. All such cases should follow up with podiatry.

PEARLS

- Cut the finger off of a latex/rubber glove and use it as a tourniquet.
- If English Anvil Nail Splitters are not available, iris scissors can be used. However, be sure not to cut or damage the nail bed (do this by applying upward pressure while cutting).
- Use the “push–pull” method of gentle, controlled use of the scissor while inserting the blades under the nail plate.
- Antibiotics are usually NOT required.
- Instruct the patient to follow up with podiatry if there is no improvement.

RESOURCES

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CHAPTER

29

Procedures for Treating Subungual Hematoma

Patrick Cotter

BACKGROUND

A subungual hematoma is a collection of blood between the nail bed and the nail, often the result of trauma to the digit such as a blow or crush injury. These injuries may be accompanied by a fracture to the distal phalanx of the affected digit. In addition to direct trauma, subungual hematomas may occur during sporting activities with repetitive trauma to the toes (e.g., long-distance runners). A full history establishing the cause of the injury should be obtained. Nonaccidental injury in children, elder abuse, or systemic conditions need to be considered by the practitioner.

Examination should include the corresponding digit on the opposite hand or foot, noting any open wounds and deformities to the digit. The integrity of the nail should also be assessed for any sign of detachment or avulsion. After assessing circulation and sensation, assess flexor and extensor tendon function on the injured digit. Record the percentage of nail bed covered by the subungual hematoma. Traumatic injuries resulting in subungual hematoma should have x-ray evaluation for potential fracture of the distal phalanx. All patients presenting with painful subungual hematoma should be offered appropriate analgesia.

PATIENT PRESENTATION

- Throbbing pain to the affected digit
- Dark-red or blue/black discoloration of the nail

TREATMENT

Treatment of subungual hematomas depends on the amount of nail affected. When the area is less than 50% and painless, the injury often requires no further intervention. For painful hematomas of any size or those covering more than 50% of the nail bed, decompression (trephination) should be performed. For hematomas affecting 50% or more of the nail, the incidence of associated nail bed laceration increases substantially. Historically, it was considered necessary to remove the nail when a subungual hematoma involved 50% or more in order to repair the nail bed. More recent evidence indicates that leaving the nail in situ does not affect the cosmetic appearance or function of the nail and digit. Furthermore, nail removal and nail bed repair for large subungual hematoma with an intact nail and nail margin were found to be more expensive than conservative management and not justified (Dean & Becker, 2011). In addition, there was no evidence to support the repair of nail bed when x-rays reveal a minimally displaced fracture of the distal phalanx. If the patient's nail is not intact or the integrity of the digit is threatened, then nail removal and nail-bed repair should be considered (Fastle & Bothner, 2020). Nail-bed repair is described in Chapter 32, Procedure for Nail Avulsion.

Nail trephination provides quick relief of painful subungual hematomas on intact nails. There are two principal methods for nail trephination—the heat method and the drill method. The heat method is preferred because of the potential for nail-bed trauma when using the drill method.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Patients wearing false/acrylic nails (if using electrocautery/heat)

SPECIAL CONSIDERATIONS

- Associated nail avulsion or nail-fold injury
- Moderate to severely displaced fracture of the distal phalanx
- Associated flexor or extensor tendon injuries
- Be aware that other medical conditions may present with the appearance of subungual hematoma (e.g. Kaposi's sarcoma, melanoma, splinter hemorrhages seen with endocarditis)

PROCEDURE PREPARATION

Heat Method

- Gloves
- Electrocautery/paper clip with heat source
- Gauze
- Skin cleanser (nonalcohol-based due to flammable properties)

Drill Method

- Gloves
- 18-g needle
- Gauze
- Skin cleanser

PROCEDURE

Although analgesia may be used to manage pain, local or regional anesthesia is rarely required for nail trephination. In severely distressed patients, digital nerve block can be considered to manage pain.

For both methods of nail trephination, the clinician should don gloves and then clean the affected nail and digit with skin cleanser. An absorbent, protective pad should be placed under the patient's hand. Sterile technique is not required, but may help to reduce introduction of other contaminants.

Heat Method

- Apply heated point (electrocautery or heated paper clip) at 90-degree angle to the nail plate at the center of the subungual hematoma while holding the affected digit steady (**FIGURE 29.1**).
- Apply gentle pressure until feeling of "give" occurs under the heated point.
- Apply gentle pressure to the nail to expel blood from under the nail plate.
- Place a dry dressing over the affected nail.

Drill Method

- Apply needle point at 90-degree angle to the nail plate at the center of the subungual hematoma while holding the affected digit steady (**FIGURE 29.2**).
- Roll the thumb and index finger back and forth while holding the needle to the nail plate.
- Be careful not to penetrate the nail bed when the needle breaks through the nail plate.
- Apply gentle pressure to the nail to expel blood from under the nail plate.
- Apply a dry dressing over the affected nail.

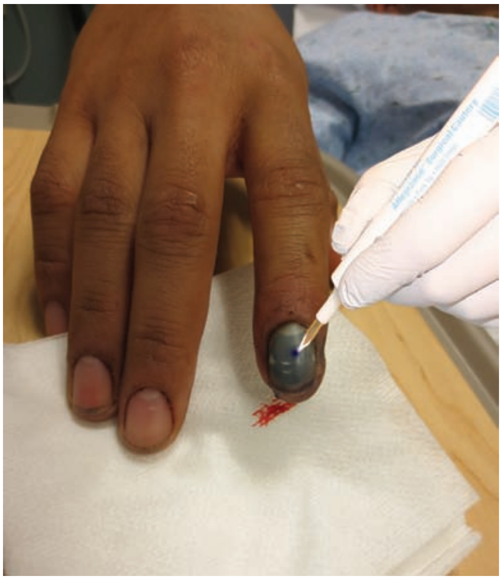

FIGURE 29.1 Trephination—heat method.

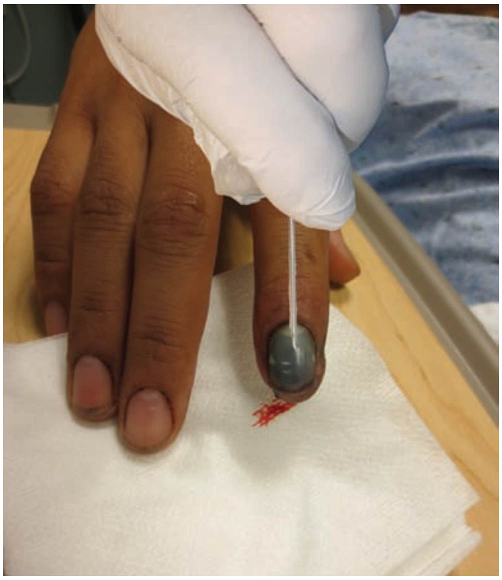

FIGURE 29.2 Trephination—drill method.

POSTPROCEDURE CONSIDERATIONS

- Elevate the affected limb to reduce throbbing and pain.
- Educate the patient on pain management, the importance of keeping the area clean, and signs and symptoms of infection, requiring a return visit.

EDUCATIONAL POINTS

- Trephination should be considered when the subungal hematoma is 50% or greater or painful regardless of size.
- Heat method is preferred as less painful for the patient.
- No evidence to support the use of antibiotics in absence of infection.
- No need to remove the nail regardless of the size of the subungal hematoma unless the nail margin(s) and/or nail are disrupted.
- No need to remove nail if intact.
- No need to remove nail if there is undisplaced/minimally displaced fracture of the distal phalanx.
- Be cautious with nontraumatic subungual hematoma as it may signify underlying disease.

COMPLICATIONS

- Infection

PEARLS

- Light tubular gauze applied over digit, including nail, can encourage drainage of blood and assist in preventing accumulation of the hematoma.
- Digital anesthesia is rarely required before trephination.
- Upon successful trephenation and adequate evacuation of the subungal hematoma, relief of pain should be immediate and complete.
- Maintain suspicion for a distal phalanx fracture.

RESOURCES

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CHAPTER

30

Procedures for Managing Paronychia

Allison Rusgo

BACKGROUND

Paronychia, defined as a localized and superficial infection of the lateral aspect of the nail fold, or perionychium, is one of the most common hand infections. Incidentally, the most common infections of the hand are bite wounds (dogs and cats), paronychia, felon, flexor tenosynivitis, and septic arthritis. Most often, it affects one digit and involves traumatic disruption of the natural barrier between the nail fold and nail plate. This occurrence compromises the tissue and allows for bacteria to colonize the small space. The infection then spreads around the nail plate, but it can also effect the eponychium, or cuticle. Once this occurs, patients present with tenderness, erythema, edema, warmth, fluctuance, and possible purulent drainage around the affected eponychial tissue.

Acute paronychia infections occur because of risk factors such as minor trauma such as nail biting, chewing of the periungal tissue, aggressive manicures, use of artificial nails, or embedded lateral nails ("hangnails"). In pediatrics, these infections are common in patients who suck their fingers.

Most Common Pathogens Causing Acute Paronychia

- *Staphylococcus aureus* (most common)
- *Streptococcus pyogenes*
- *Eikenella corrodens*
- Anaerobic organisms
  - *Provotella* spp.
  - *Fusobacterium nucleatum*
  - Gram-positive cocci
  - *Peptostreptococcus* spp.

Paronychial infections can also be chronic (lasting longer than 6 weeks) with different etiology and causative agents. Chronic paronychia can be attributed to increased handwashing, environmental factors (humidity), or irritants such as soaps and detergents. It is commonly diagnosed in swimmers, dishwashers, and medical providers due to repeated exposure to offending agents. Contact with these substances can lead to chronic inflammation, drainage, and separation of the proximal nail fold tissue. In addition, the affected tissue is susceptible to colonization from fungal or polymicrobial bacteria. The most common bacteria isolated in chronic paronychial infections are *Candida albicans* and *Pseudomonas aeruginosa*. Patients with chronic paronychia are often referred to specialists for surgical treatment, as topical medications are often unsuccessful. The remainder of this chapter focuses on the management of acute paronychia.

To aid in the diagnosis of paronychial infections (acute and chronic), clinicians can utilize bedside ultrasound. Clinically, ultrasound is becoming a popular imaging modality because it is safe, effective, efficient, and painless. It can be especially helpful for diagnosing nail pathologies because each of the nail's individual surrounding anatomical structures have different densities that can be accentuated via ultrasonographic waveforms. When viewing nails and surrounding anatomy on ultrasound, there are some basic anatomical pearls to consider (**FIGURE 30.1**). The deepest structure is the phalaynx, which is represented by a linear hyperchoic stripe inferior

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

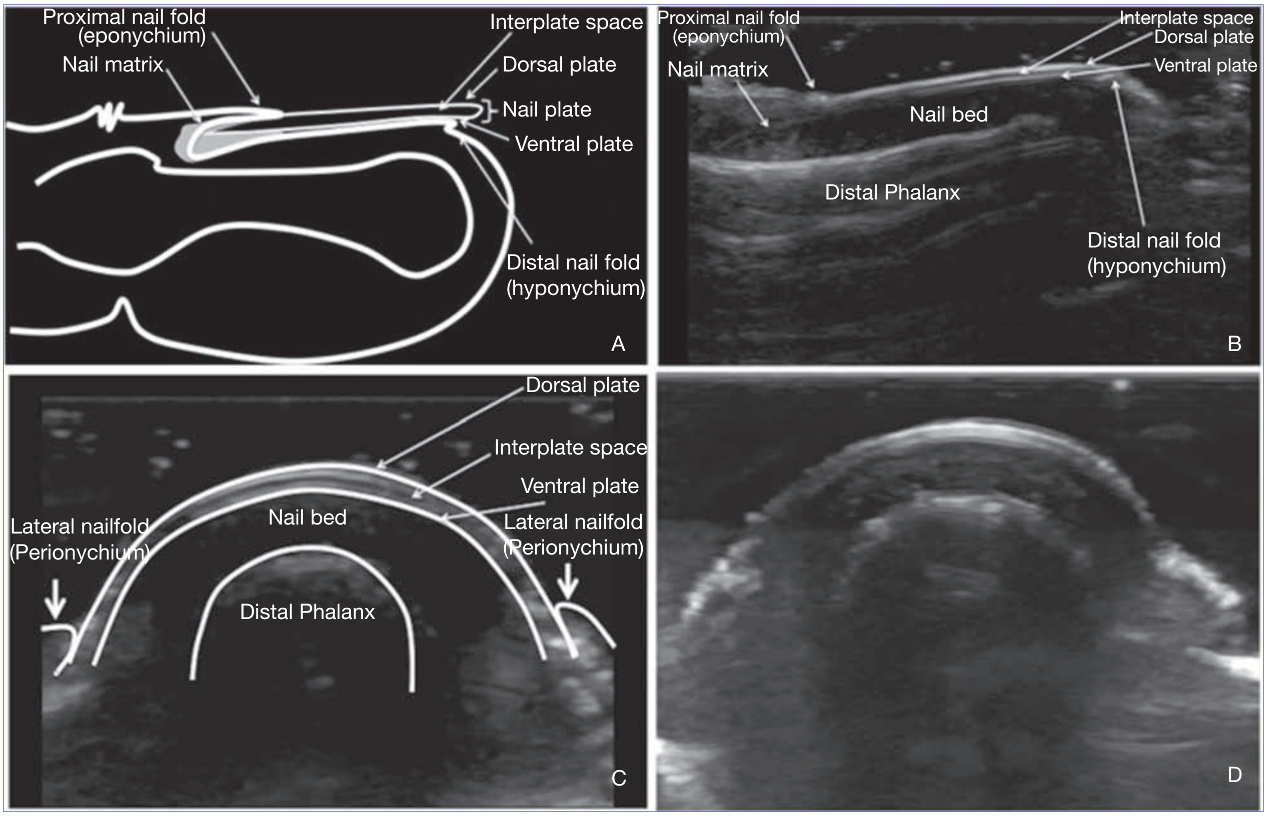

Proximal nail fold
(eponychium)
Nail matrix
Interplate space
Dorsal plate
Nail plate
Ventral plate
Distal nail fold
(hyponychium)
A
Proximal nail fold
(eponychium)
Nail matrix
Interplate space
Dorsal plate
Ventral plate
Nail bed
Distal Phalanx
Distal nail fold
(hyponychium)
B
Dorsal plate
Interplate space
Ventral plate
Lateral nailfold
(Perionychium)
Nail bed
Lateral nailfold
(Perionychium)
Distal Phalanx
C
D

FIGURE 30.1 (A) Anatomic scheme of a longitudinal view of the nail and surrounding anatomy. (B) Ultrasound, longitudinal view. Anatomic components of the nail unit and periungual zone are pointed out. (C) Anatomic scheme of a transverse view of the nail. (D) Ultrasound, transverse view. Anatomic components of the nail unit and periungual zone are pointed out.

Source: Adapted from Aluja Jaramillo, F., Quiasúa Mejía, D. C., Martínez Ordúz, H. M., & González Ardila, C. (2017). Nail unit ultrasound: A complete guide of the nail diseases. *Journal of Ultrasound*, *20*(3), 181–192. https://doi.org/10.1007/s40477-017-0253-6

to the nail bed. The nail bed itself is a highly vascular hypoechoic structure inferior to the nail plate, whereas the nail matrix is a hyperechoic area within the proximal portion of the nail bed. Each of the periungal folds—eponychium (proximal), perionchyium (lateral), and hyponychium (distal)—should be identified because of the folds' direct involvement in paronychial infections.

When performing the study, providers should use the ultrasound's power or color Doppler mode to accentuate the increased inflammation around the nail tissue. Positive ultrasonographic findings for paronychial infections include a thickening of affected periungal tissue, increased vascularization, and areas of increased echogenicity interspersed with hypoechoic areas.

PATIENT PRESENTATION

- Warm, erythematous, edematous, and tender lateral nail fold (usually unilateral but can present bilaterally)
- Fluctuant abscess with possible purulent drainage around the affected eponychial tissue

TREATMENT

For patients with an early paronychia or localized cellulitis of the affected area without fluctuance, surgical drainage is not recommended. Instead, conservative management, including warm-water soaks several times a day, and elevation. Patients with surrounding cellulitis, history of diabetes, peripheral vascular disease, or an immunocompromised state may benefit from a short course of antibiotics. An antistaphylococcal penicillin or first-generation cephalosporin is generally effective; clindamycin and amoxicillin-clavulanate may also be utilized. Patients should follow up with their healthcare provider to determine whether the infection has resolved or a collection of pus has formed, the later necessitating surgical drainage.

Similar to the treatment of other fluctuant abscesses, treatment of more extensive paronychial infections involves drainage of the infectious material to promote healing. To treat the majority of acute paronychial infections, local anesthesia is not required. This is particularly true when the affected area has turned yellow or white, indicating that the distal nerves have died secondary to the infection. In contrast, if the nerves have not infarcted and the affected area is erythematous or remains flesh colored, it is advisable to perform the drainage procedure under anesthesia with a digital block. If the infection appears to involve deeper structures of the hand, incision and drainage should not be performed and the patient should be referred to a hand specialist for operative management. There are several techniques that can be used, such as the elevation method or the simple incision method, and these are described in the subsequent sections of this chapter.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Deep space infections: If there is concern that the infection involves the deeper structures of the hand, simple incision and drainage should not be performed. The patient should be referred to a hand specialist for further management.
- Chronic paronychia infections: These do not present with fluctuance or respond to surgical drainage.
- Herpetic whitlow: Most often affects healthcare providers and immunocompromised patients; this infection presents with localized edema, clear vesicles, and a gray-appearing nail. Incision and drainage are not recommended as this infection is self-limited and resolves in several weeks; furthermore, it may cause viremia and bacterial superinfection.

SPECIAL CONSIDERATIONS

- Diabetic patients: These patients are more susceptible to complex acute and chronic paronychial infections.
- Immunocompromised patients: These patients are more susceptible to chronic paronychia.

PROCEDURE PREPARATION

- Alcohol or povidone-iodine wipes
- Absorbent pad
- Three to four towels for drapes
- 4 × 4-inch gauze pads
- Sterile gloves
- Normal saline solution
- Large syringe with splash shield (20, 30, or 35 mL; for irrigation)
- 18-gauge needle (if using 18-gauge needle technique)
- No. 11 or No. 15 blade scalpel (for complex procedures)
- Culture swab (if a culture needs to be obtained)
- ¼-inch packing material (if packing is required for further drainage)
- 19- to 22-gauge needle (for digital anesthesia)
- 1% to 2% lidocaine without epinephrine (for digital anesthesia)
- Bandage scissors
- Dressing of choice to cover wound
- Tape

PROCEDURE

- Place an absorbent pad under the treatment area.
- Using a circular motion, cleanse the affected digit with a single layer of povidone-iodine solution and allow to air dry before proceeding.
- Place drapes around the affected area and don gloves. Sterile technique is not required for this procedure. However, because of the era of resistance, it should be used whenever possible.

For Localized Infection

- Position an 18-gauge needle, bevel-up, parallel to the nail surface.
- Insert the needle at the junction between the lateral nail fold and the nail plate at the point of maximal fluctuance (**FIGURE 30.2**).
- Lift the skin around the nail fold to open the infectious cavity for drainage.
- Apply light pressure around the affected area to release any remaining pus.
- Obtain a culture (if necessary).
- Using a large syringe and splash shield, irrigate with normal saline solution and pat dry.
- Insert a small amount of ¼-inch packing material under the nail fold if necessary (not required but can be helpful to ensure complete drainage of purulent material).
- Apply a sterile dressing to affected area (**VIDEO 30.1**).

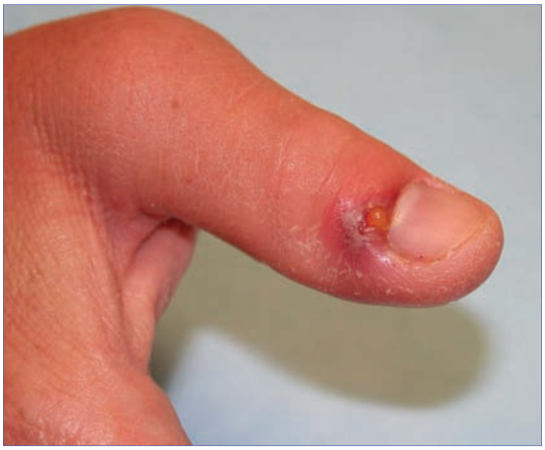
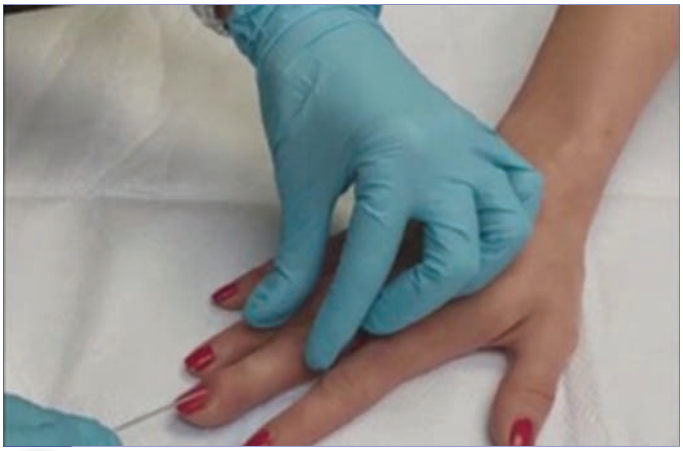


FIGURE 30.2 Area of localized infection representing an acute paronychia.



VIDEO 30.1 Paronychia simple incision.

For Complex Infection

- Perform digital block (see Chapter 18).
- Once area is anesthetized, place the scalpel parallel to the nail surface and gently advance it under the eponychium, ensuring the nail bed remains intact (**FIGURE 30.3**)
- Apply gentle pressure to the affected area to express the infectious material.
- Obtain a culture (if necessary).
- Using a large syringe and splash shield, irrigate area with normal saline solution and dry.
- Insert a small amount of ¼-inch packing material under the nail fold.
- Apply a sterile dressing to cover affected area.

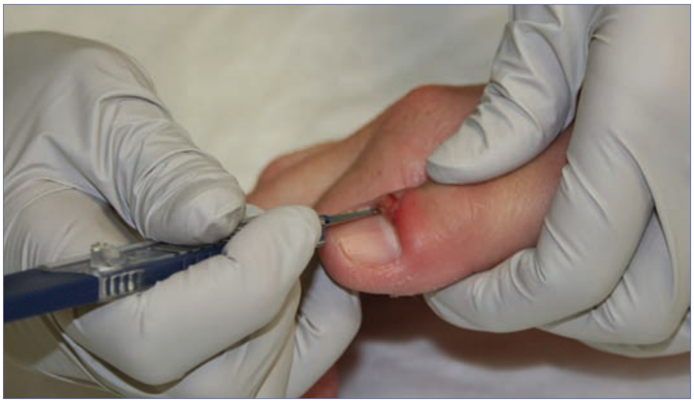


FIGURE 30.3 Incision and drainage of paronychia using scalpel technique.

ULTRASOUND GUIDANCE

- Ensure affected nail is unpolished prior to completing scan.
- Apply a layer of ultrasound gel to the affected nail to optimize signal (wave) return and image creation.
- Use a high-frequency linear transducer (15 Mhz or higher) to appreciate the nail's intricate layered structures.
- Begin by examining the nail in two-dimensional (2D) mode before transitioning to color and power Doppler modes.
- All scans should be completed in transverse and longitudinal planes.
- In both planes, identify the ungual and periungual regions to note localized areas of inflammation or any abnormalities in echogenicity or blood flow (**FIGURE 30.4**).

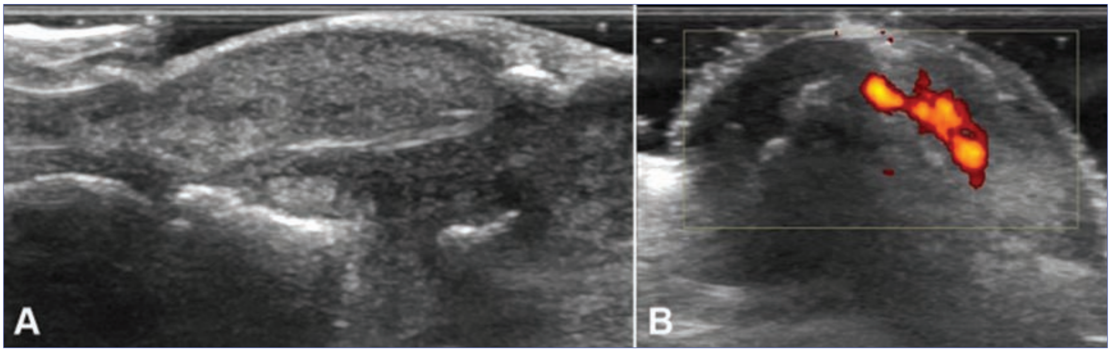


FIGURE 30.4 Paronychia. Ultrasound (A) longitudinal and (B) transverse views. Areas of increased echogenicity are interposed with hypoechoic areas and increased vascularization during power and color Doppler analysis.

Note: Areas of increased vascularization and echogenicity within the periungal tissues can highlight the presence of an acute paronychia.

Source: Aluja Jaramillo, F., Quiasúa Mejía, D. C., Martínez Ordúz, H. M., & González Ardila, C. (2017). Nail unit ultrasound: A complete guide of the nail diseases. *Journal of Ultrasound*, *20*(3), 181–192. https://doi.org/10.1007/s40477-017-0253-6

POSTPROCEDURE CONSIDERATIONS

- There is rarely a need for hospital admission or intravenous (IV) antibiotics unless there are extenuating circumstances such as deep space infection, significant concomitant cellulitis, or a severely immunocompromised patient with systemic symptoms.
- For simple paronychial infections that have been successfully drained, oral antibiotics are rarely required. Consider a short course of antistaphyloccal agents (i.e., cephalexin 500 mg TID for 7 days) in immunocompromised patients, patients with vascular insufficiency, or in cases with mild/moderate cellulitis surrounding the affected digit.
- Instruct patients to seek immediate medical attention if new or worsening symptoms of infection develop and encourage a follow-up appointment within 2 days of the initial procedure to assess healing and remove packing (if utilized).

DRAINAGE

- If the paronychia is small, only a small amount of drainage may be expressed.
- Consider alternative diagnoses, such as herpetic whitlow, if pus drainage is less than expected based on the amount of edema.

INGROWN NAIL

- If an ingrown nail is present or the pus collection is under the nail, it may be necessary to elevate the nail or create a small incision proximal to the nail fold to express the pus.

MOBILE NAIL

- If the nail is mobile, complete nail removal may be necessary.

EDUCATIONAL POINTS

- Elevate the affected area several times a day to promote healing.
- Protect the wound with a sterile bandage.
- In cases of an early paronychia without fluctuance or localized cellulitis, instruct patients to perform warm-water soaks three or four times per day for several days; this process can help alleviate the infection or draw the pus to a localized area for drainage by a healthcare provider (patients can also perform these soaks after drainage if packing was not placed to help with continued healing).
- Apply topical antibiotic to wound.
- Instruct patients to keep fingernails clean, avoid nail biting and finger sucking, don gloves when exposed to contact irritants, and thoroughly dry hands after excessive exposure to moisture.
  - Patients with chronic paronychial infections should be educated on the importance of avoiding contact irritants and keeping their hands dry. These patients may also benefit from antifungal medications and referral to hand specialists for additional management.
  - Among diabetic patients, encourage tighter glycemic control and avoidance of minor fingernail trauma.
  - Immunocompromised patients should minimize fingernail trauma.

COMPLICATIONS

- Excess bleeding—If excess bleeding occurs from an incision made during the procedure, apply direct pressure to the area until bleeding has ceased.
- Insufficient drainage—If the procedure was performed without significant expression of infected material, the affected area should be irrigated sufficiently and packed with ¼-inch gauze to promote further drainage of pus.
- Deep space infection—If while performing the procedure it is recognized that the infection has spread to deeper structures of the upper extremity, complete the localized procedure and refer the patient to a hand specialist for further surgical management.
- Progressive infection—If the localized paronychial infection spreads to surrounding tissues causing cellulitis or lymphangitis, the patient should be treated with oral or IV antibiotic therapy depending on the extent of the infection and the clinical presentation.
- Reoccurrence—If a paronychial infection reoccurs despite successful drainage of the initial infection, the patient should be referred to a hand specialist for further evaluation and consideration should be given to underlying diseases (e.g., autoimmune/immunologic disorders or cancer) or foreign body.

PEARL

- Ethyl chloride can be used topically to decrease the pain experienced with incision or puncture of the abscess.

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CHAPTER

31

Procedures for Treating Felons

Theresa M. Campo and Shannon M. Keating

BACKGROUND

A felon is an infection that involves the pulp of the distal finger or thumb. The finger pulp or pad is made up of numerous small compartments that are divided by fibrous septa running from the bone to the skin. The compartments contain eccrine sweat glands and fat globules, which are vulnerable to bacterial invasion. These pulp abscesses account for 15% to 20% of all hand infections. The thumb and index finger are the most commonly affected digits.

Felons are commonly caused by trauma, foreign body (splinter, thorn, etc.), or an untreated paronychia. The most common infectious agents are *Staphylococcus aureus*, including community-acquired methicillin-resistant *S. aureus* (CA-MRSA) and other methicillin-resistant strains. However, mixed infection with *Staphylococcus* and *Streptococcus* as well as Gram-negative infection can occur.

Infection leads to inflammation, which increases compartment pressures and leads to ischemia. Ultimately, tissue necrosis will occur and bacterial invasion of the periosteum is possible. If left untreated, or if therapy fails, severe complications can result, including osteomyelitis, necrosis, septic arthritis of the distal interphalyngeal joint, and flexor tenosynovitis.

The diagnosis of felon is clinical based on suspicion and physical exam. It is important to rule out possible causes of initial infection, such as a foreign body. Therefore, a radiograph of the affected digit is appropriate when there is concern for foreign body or osteomyelitis. Obtaining a Gram stain and wound culture can help with infections that are difficult to eradicate, although not typically available for 48 to 72 hours.

PATIENT PRESENTATION

- Aching pain early, severe throbbing pain later (worse in the dependent position)
- Erythema (cellulitis)
- Firm/tense swelling of the distal fat pad (does not extend proximal to distal interphalyngeal joint space)
  - Fluctuance may be present early, but is usually firm at the time of patient presentation
- Systemic signs are usually not present

TREATMENT

If treated early, felons can be effectively managed with simple incision and drainage in the area of maximum swelling and tenderness, coupled with oral antibiotics. Treatment plans should include tetanus prophylaxis, warm compresses or soaks (to promote local vasodilation and delivery of inflammatory cells), and elevation above the level of the heart (helping to reduce edema by improving venous and lymphatic drainage). Arm slings do not provide adequate elevation. Radiographs to rule out a foreign body and osteomyelitis will help guide treatment.

NOTE **Decreased pain without intervention can be a sign of extensive necrosis and nerve degeneration.**

Broad-spectrum antibiotics should be utilized, typically for 7 to 10 days. Commonly used antibiotic regimens include clindamycin (alone) or a combination of cephalexin (Keflex) and trimethoprim/sulfate (Bactrim). Amoxicillin/clavulanate (Augmentin) provides coverage for suspected infection from oral flora bacterium, such as with patients who bite their nails. However, the most appropriate selection of oral antibiotics is based on current recommendations by geographic region so as to consider local resistance patterns and include coverage of typical pathogens.

However, incision and drainage may provide only temporary symptomatic relief as the infection may be more extensive than symptoms and clinical appearance suggest. Treatment for severe infections will require hospitalization, intravenous antibiotics, and debridement of the abscess cavity in the operating room by an orthopedic or hand surgeon.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Complex cases require consultation with an orthopedic or hand surgeon. If in doubt, consultation is recommended, especially if there is concern for osteomyelitis or flexor tenosynovitis.
- Vesicles indicate herpetic infection and incision and drainage should not be performed.

SPECIAL CONSIDERATIONS

- Diabetics
- Immunocompromised patients

PROCEDURE PREPARATION

- Absorbent pads
- Skin cleanser
- Lidocaine or bupivacaine for digital block (see Chapter 18, Procedures for Performing Digital Anesthesia)
- 10-mL syringe
- 25- or 27-gauge needle for injection of anesthetic
- No. 11 scalpel blade (a No. 15 scalpel blade can be used if a No. 11 is not available)
- Scissors
- Culture swab
- Normal saline solution for irrigation
- Large syringe (20, 30, or 35 mL)
- Gauze pads
- Kling or gauze for wrapping
- Tape

NOTE **Premade suture kits usually have the instruments and equipment used in this procedure. Check with your institution for kit contents.**

PROCEDURE

- Premedicate with oral pain medicine. A nonnarcotic should be used if patient is driving home.
- Digital block anesthesia may be more effective than local anesthesia.
- Utilize sterile technique to prevent extending the infection.
- Cleanse the skin with betadine using a circular motion to free debris and bacteria.
- Place an absorbent protective pad under the treatment area.
- Drape the patient to maintain a clean area.

Although the evidence varies regarding the different approaches used for incision and drainage of a felon, the most commonly used methods with the least complications are discussed here. Current evidence no longer supports fishmouth, hockey stick, and through and through incision methods as they can lead to nerve and blood vessel damage and a painful fingertip. Overall, the best methods minimize interference with sensate areas of the finger pad. For this reason, incisions of the pincer surfaces should be avoided when possible. Careful attention must be paid when incising a felon because of the potential for injury of the tendons, nerves, and vasculature.

The incision should be made along the ulnar aspect of digits II to IV (index, middle, and ring finger) and the radial aspects of digits I and V (thumb and little finger). Disruption of the fibrous septa is not recommended as it results in fingertip instability.

Central Longitudinal Incision

A central longitudinal incision in the midline (**FIGURE 31.1**) is effective without the serious iatrogenic complications observed with other methods. To avoid flexor tendon damage, the incision should not extend to the flexor crease of the DIP.

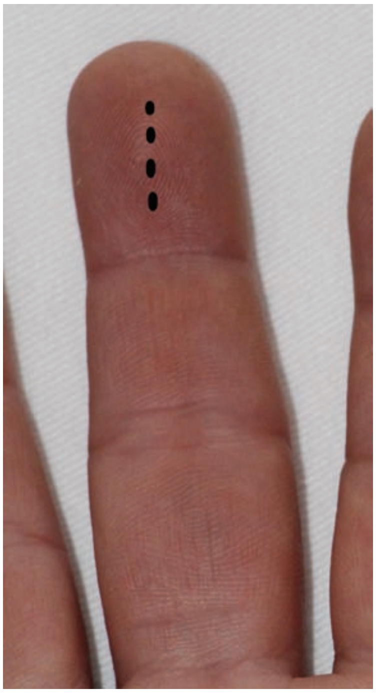

FIGURE 31.1 Central longitudinal incision through the midline.

Unilateral Longitudinal Incision or Transverse

A unilateral longitudinal incision through the fat pad (**FIGURE 31.2**) has greater risk of complication as neurovascular bundles can be injured, causing ischemia. However, this approach minimizes interference with sensate areas of the finger pad.

Incision is started 0.5 cm distal to the DIP joint crease and dorsal to the neurovascular bundle of the fingertip. Extension past the DIP crease can cause flexor tendon damage.

- Bluntly dissect the subcutaneous tissue to break up the loculations with a hemostat.
- Investigate and remove any foreign bodies or necrotic tissue.
- Irrigate the wound with sterile normal saline (avoid high-pressure irrigation as it may push bacteria onto the tendon sheath, extending infection into the DIP joint).
- Loosely pack the wound (usually requires only a small piece of packing).
- Dress the wound with gauze and Kling bandage.
- Immobilize the finger.

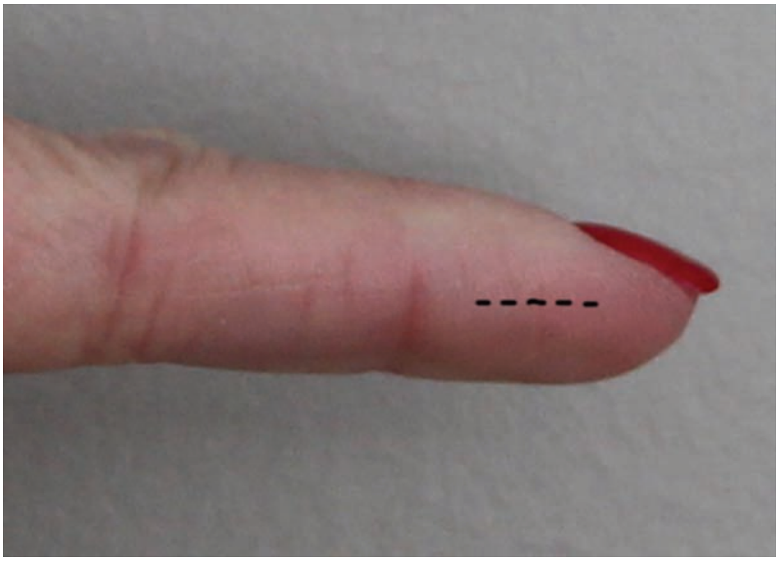

FIGURE 31.2 Unilateral longitudinal incision through fat pad.

POSTPROCEDURE CONSIDERATIONS

- Oral antibiotics (see previous section for choice selection)
- Chronic felons or those not responding to treatment should be referred to a hand specialist
- If necessary, administer narcotic analgesia with instructions to avoid operating heavy machinery and alcohol intake
- Uncomplicated felons can be discharged home with drain removal and recheck within 48 hours
- Discharge teaching
- Elevate above the level of the heart to relieve throbbing and pain
- Warm compresses or warm soaks daily to promote continued drainage and assist with secondary healing
- Prompt follow-up with wound check and packing removal recommended within 48 to 72 hours; if there is worsening of symptoms before this time, instruct the patient to return to the ED immediately for surgical consultation

EDUCATIONAL POINTS

- Elevate
- Warm compresses
- Remove packing in 48 to 72 hours
- Pain medication—Risks and benefits depending on class of medication

COMPLICATIONS

Multiple complications exist with felons, making treatment imperative with early consultation for any concern of severe infection.

- Untreated felons may lead to skin necrosis, sinus tract formation, and/or chronic drainage.
- Dorsal spread of the infection may lead to phalangeal tuft necrosis or osteomyelitis.

Complications may also result directly from the incision-and-drainage procedure, in part due to the technique utilized.

- Crossing the DIP flexor crease increases the risk of infection spread, flexor tenosynovitis, septic arthritis, and proximal osteomyelitis.
- Incisions involving the neurovascular bundle may result in vascular insufficiency, fingertip anesthesia, or neuroma (nerve tissue growth).
- Longitudinal volar fat-pad incisions can result in thick scarring and/or fingertip anesthesia.

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CHAPTER 32

Procedure for Nail Avulsion

Eric D. Roberts

BACKGROUND

Nail avulsion may be defined as the action of pulling or tearing the nail away from a digit. This may occur as a result of a traumatic event, leaving the nail either partially or completely separated from the finger or toe. Differential diagnosis of nail avulsion should be considered for patients presenting with damage to the nail as a result of trauma. Nail avulsion may also occur as an elective procedure in the treatment of an ingrown nail.

Nails serve to protect the tips of our digits. This is particularly important in fingers as the tips help with fine motor skills such as pincher grip, scratching, and picking up small objects. The tips of all digits are important in tactile sensation. Damage to the nail may compromise these actions. Beyond these important roles, the nails also have cosmetic significance. Therefore, it is important to maintain structural integrity of the tips of the digits to ensure healthy nail growth and physiologic function.

Hand injuries may occur at a rate of 11.6 per 1,000 children under the age of 18 and may account for as many as 2% of all pediatric visits to the ED. The most frequently injured part of the hand are the digits with the thumb, index, fifth, and ring fingers being involved in 19%, 14%, 13%, and 11% of cases, respectively (Fetter-Zarzeka & Joseph, 2002). Nail bed damage may occur in as many as 15% to 26% of hand injuries (de Alwis, 2006). When evaluating patients with nail bed injuries, it is important to consider all associated anatomic structures of the distal digit as the skin, nail plate, nail bed, and distal phalanx may be involved. Maintenance of these structures is necessary to preserve physiologic function.

Anatomy

The following anatomic structures constitute the nail (**FIGURE 32.1**):

- Perionychium: The soft tissue that surrounds the nail plate; this constitutes the natural nail fold
- Hyponychium: The junction between the nail bed and fingertip skin
- Cuticle: The area of skin where the nail grows out of the finger—provides protection to the nail matrix
- Lunula: White, half-moon cells located at the nail base
- Eponychium: The proximal dorsal fold that lies on the surface of the nail
- Nail matrix (nail bed): Must be healthy to provide support and ensure normal contour; consists of the skin beneath the nail plate
    - Germinal nail matrix: Area of nail bed proximal to the lunula; 90% of nail growth occurs here (relatively thick); must be healthy to ensure growth
    - Sterile matrix: Area of nail bed that is distal to the lunula (relatively thin)

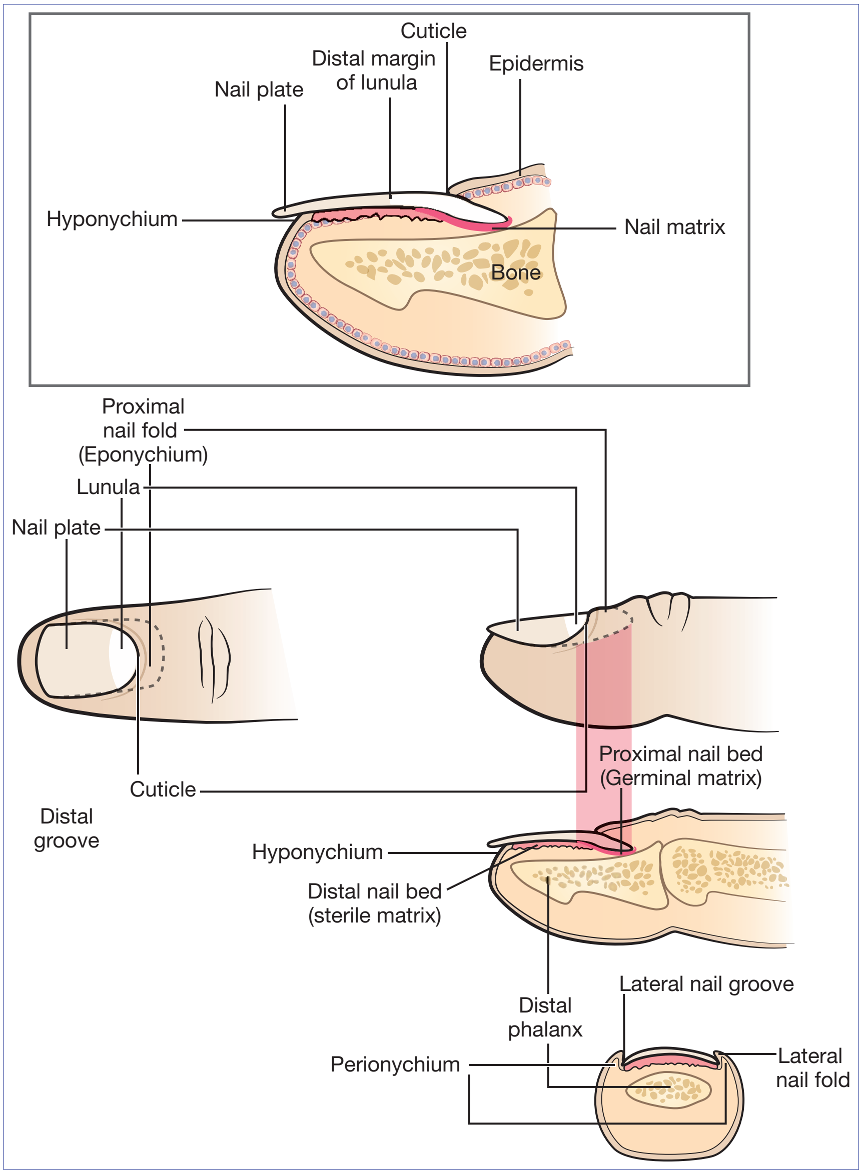

Cuticle
Distal margin of lunula
Epidermis
Nail plate
Hyponychium
Nail matrix
Bone
Proximal nail fold (Eponychium)
Lunula
Nail plate
Cuticle
Distal groove
Proximal nail bed (Germinal matrix)
Hyponychium
Distal nail bed (sterile matrix)
Lateral nail groove
Distal phalanx
Perionychium
Lateral nail fold

FIGURE 32.1 Nail anatomy.

PATIENT PRESENTATION

- Minor injuries—These are injuries in which the nail is intact, a subungual hematoma covers less than 50% of the nail bed, with no underlying fracture, and the nail remaining within the surrounding nail fold.
- More extensive injuries are considered when:
  - Subungual hematoma is more than 50% of the nail surface.
  - The nail is detached from surrounding tissue.
  - There is injury to the proximal nail at the germinal matrix.
    - These are significant as future nail growth may be affected.
  - The nail bed is disrupted.
    - May occur in as high as 60% of cases with a subungual hematoma that is greater than 50%.
    - Injury to the nail bed epithelium may regenerate without permanent dystrophy.
    - Injury to the hyponychium can result in permanent oncholysis.

  - There is underlying fracture.
    - Approximately 50% are associated with nail bed injury.
    - These are likely to be present when a hematoma occupies more than 50% of the nail field.
- Classification systems exist for the purpose of articulating the extent of injury determining need for surgical referral and management.
  - Pulp Nail Bone (PNB) classification of fingertip injuries (**TABLE 32.1** and **FIGURE 32.2**)
    - Advantages: Precise descriptor, ease of use
    - Disadvantage: More research is necessary to determine clinical cutoffs to guide management strategies
  - Amputations of the finger may be classified by zones, relative to arterial structures (**FIGURE 32.3**), which may be helpful if referring to a hand surgeon.
    - Zone 1: Damage to the proximal central pulp artery
    - Zone 2: Damage to the branch of the central pulp artery
    - Zone 3: Damage to the distal central pulp artery
    - Zone 4: No injury to the central pulp artery, only to the lateral pulp artery

TABLE 32.1 **The PNB Classification for Fingertip Injuries**

Pulp	Nail	Bone
0: No injury 1: Laceration 2: Crush 3: Loss—distal, transverse 4: Loss—palmar, oblique, partial 5: Loss—dorsal, oblique 6: Loss—lateral 7: Loss—complete	0: No injury 1: Sterile matrix laceration 2: Germinal matrix laceration 3: Crush 4: Proximal nail bed dislocation 5: Loss—distal third 6: Loss—distal two-thirds 7: Loss—lateral 8: Loss—complete	0: No injury 1: Tuft fracture 2: Comminuted, nonarticular 3: Articular 4: Displaced basal 5: Tip exposure 6: Loss—distal half 7: Loss—subtotal 8: Loss—complete

PNB, pulp, nail, bone.

Source: Adapted from Evans, D., & Bernardis, C. (2000). A new classification for fingertip injuries. *Journal of Hand Surgery, 25B*, 58–60. https://doi.org/10.1054/jhsb.1999.0305

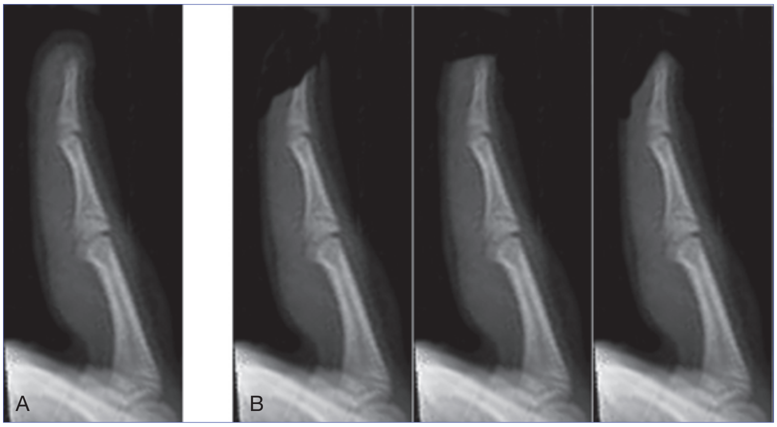


FIGURE 32.2 PNB classification of fingertip injuries. (A) Normal. (B) Demonstrating fingertip injury.

PNB, Pulp Nail Bone.

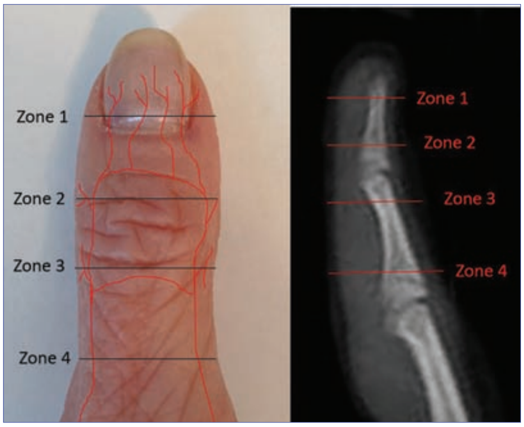


FIGURE 32.3 Amputations of the finger may be classified by zones.

Source: Courtesy of Theresa Campo.

TREATMENT

Minor injuries may be treated simply with thorough cleaning and dressing. Nail trephination may be considered as conservative treatment if a subungual hematoma is present. Although there is controversy regarding indications for nail avulsion in the evaluation and treatment after traumatic injury, the following guidelines are most consistently applied:

- When the nail plate is removed, it is commonly replaced with a dressing to maintain adequate space and precise alignment between the germinal matrix and the proximal nail fold. This may minimize adhesions in the proximal nail fold and allow for the growth of new nail.
- Replacing the nail also serves to splint any underlying fracture and may remain sutured in place for several weeks until the fracture is stabilized.
- When the native nail is not available to be replaced as a splint, alternative splints can be fashioned from syringes; plastic or commercially available silicone plates may be used. Use of these has been shown to result in twice as many infections and statistically greater nail growth deformities.
- There is risk for negative sequelae when the germinal matrix is injured. Permanent damage to the matrix results in nail plate dystrophy. Failure to free the nail plate from the underlying matrix at the proximal points when avulsing the nail plate results in tearing the matrix and unnecessary trauma.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Risks and benefits should be scrutinized in patients who are immunocompromised. It may be reasonable to take a conservative approach in this patient population, which may be at risk of infection.

SPECIAL CONSIDERATIONS

- Understanding the mechanism of injury will help predict damage to underlying structures. This may guide evaluation and treatment, including the need for x-ray.
- Lacerations to the proximal nail fold should be assessed and repaired accurately as this is the location of the dorsal root of the germinal matrix. Inadequate repair may result in poor nail growth.

PROCEDURE PREPARATION

- Gather supplies.
  - Nail elevator
    - Use of nail elevator is ideal as it is less traumatizing to the nail bed.
    - In the absence of a nail elevator, iris scissors may be used to separate the nail at the proximal nail fold as well as from the nail bed. Iris scissors are thin and may also minimize trauma from the procedure.
    - Less ideal instrumentation, but readily available, are scissors available in a standard suture kit.
  - 6-0 absorbable suture for nail bed; 5-0 nonabsorbable suture for securing nail plate
  - Head magnifier—May facilitate best repair and provide most accurate assessment with magnified visualization
  - Chlorhexidine—Has demonstrated superiority to betadine washing for prevention of postprocedure infection
  - Lidocaine or bupivacaine—Higher concentrations may give longer lasting anesthesia
- Position the patient.
  - Position should be ideal for clinician comfort to maximize patient compliance during procedure.
  - Patient position should offer the provider comfortable access to the working field, allowing for better attention and optimal physical execution during the procedure.

PROCEDURE

- Provide anesthesia by digital block (see Chapter 18).
- Insert a nail elevator or scissors under the proximal nail fold to elevate the eponychium from the nail. Back-and-forth movements from one side to the other are used to separate the nail fold from the underlying nail (**VIDEO 32.1**).
- Then, introduce the elevator under the nail through the hyponychium to the matrix.
  - Push forward and retract from one side to the other to free the nail from the bed and matrix.
  - If using scissors, while closed, insert scissors between the nail plate and matrix; opening and spreading the scissors will accomplish separation of the plate from matrix (**VIDEO 32.1**).

- Examine the nail bed in a bloodless field using tourniquet or commercial device (**VIDEO 32.2**).
  - Do not leave tourniquet in place more than 20 minutes.
- Clean wound with normal saline irrigation and chlorhexidine solution.
- Repair any underlying laceration (**VIDEO 32.3**).
  - Secure native nail as possible, with goal to keep eponychial fold open.
  - Partial nail may be used if only proximal section is available.
  - May use single sutures to tack down nail edge at each corner of the paronychial fold (**FIGURE 32.4**).
    - This technique may risk having nail slide out at the eponychial fold (proximally) and paronychial folds (laterally).
- Tissue adhesive has been found to provide nail bed laceration closure with clinical outcomes similar to suture.

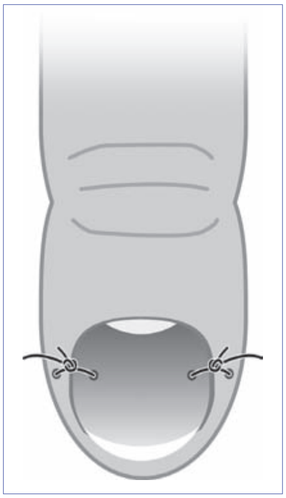
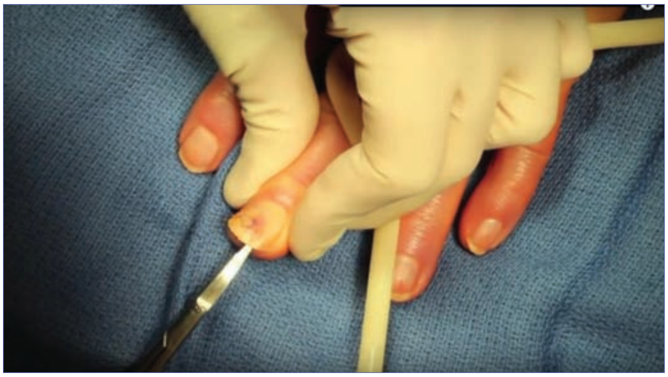


FIGURE 32.4 Illustration depicting single sutures on nail edges.



VIDEO 32.1 Removal of nail.

Source: Reproduced with permission from Dr. Thomas McClellan. Retrieved from https://www.youtube.com/watch?v=hYDggOKqG5A

VIDEO 32.2 T-Ring© application.

Source: Reproduced with permission from The T-RING. Retrieved from https://www.youtube.com/watch?v=ezhKfp5OFtU

VIDEO 32.3 Repair of nail bed laceration.

Source: Reproduced with permission from Brian Lin, MD. Retrieved from https://www.youtube.com/watch?v=H1sOZ9J1bEw

POSTPROCEDURE CONSIDERATIONS

- Dressing material should be padded to absorb blood; use of tube gauze dressing with underlying petroleum-impregnated mesh to minimize likelihood of dressing adherence to the wound is ideal
- Elevate extremity 24 to 48 hours to reduce edema and pain
- Pain management
- Tetanus immunization
- Postprocedure antibiotics as indicated; inconclusive evidence to support the routine use of prophylactic antibiotics in all fingertip injuries; postprocedure risk factors include the following:
  - History of diabetes
  - Immunosuppression
  - Concurrent burn
  - Grossly contaminated wounds
- Common organisms that may cause postprocedural infection are the following:
  - *Staphylococcus aureus*
  - *Streptococci*
  - Methicillin-resistant *S. aureus*
  - Or mixed flora
- Antibiotic recommendations
  - Clean, isolated injuries with simple lacerations and no risk factors—no prophylactic antibiotics
  - Contaminated, dirty wounds, including human or animal bites, or presence of risk factors—targeted antibiotic use
  - Open fractures—Prophylactic antibiotics targeting Gram-positive bacteria, include Gram-negative coverage for high-grade injuries
- Splints
  - Even if no underlying fracture, a volar splint will be beneficial to minimize sensitivity from tactile stimulation. Padded aluminum splints, either fabricated to individual patient or a prefabricated finger cot or frog splint, are most effectively used.
- Patient education
  - May leave initial dressing in place for 24 hours. After this time, dressing may require soaking in order to be removed without disrupting underlying repair.
  - Perform wound care twice daily; clean with soap and water, and then apply antibiotic ointment to minimize infection risk.
  - The existing nail will be displaced by new nail growth in 1 to 3 months.
- Follow-up plan
  - Significant injuries or those at risk for infection may require close follow-up.
  - Suture used to reattach an existing nail can be removed in 3 weeks.
- Consultation and/or referral to hand surgeon are needed for:
  - All displaced fractures
  - All complex nail bed lacerations, injuries with partial or complete loss of the nail bed, and those with significant avulsions of the nail folds
  - All open fractures with significant pulp or nail bed defects (>1 cm)
  - Any exposed distal phalanx with overlying loss of tissue; a flap procedure and possible skin graft may be needed
- Healed fingertips are often sensitive and sometimes painful and therefore rehabilitation of the fingertip may be necessary to allow for adapting the sensitive part to gradually increasing duration and frequency of stimulation

EDUCATIONAL POINTS

- Desired primary outcomes include maintenance of fingertip function, promotion of nail growth, prevention of future nail deformity, and minimization of adverse events (wound infection, distal necrosis, hypertrophic scaring, and growth arrest)
- Secondary outcomes include patient satisfaction, pain and sensation, time to healing, and need for secondary procedures
- Rate of nail growth—0.1 mm/day for finger (2–3× that of toes)

COMPLICATIONS

- In contaminated wounds, immediate exploration and a thorough washout are essential as infection can be a serious issue leading to flexor sheath infection and distal amputation.
- Postprocedural cigarette smoking may lead to risk of ischemic complications and delayed wound healing.
- Failure to repair a nail bed laceration may lead to onycholysis, dystrophy, malalignment, pterygium formation, or split nail.
- Postoperative infection may present in varied ways: felon, compartmental cellulitis, lymphangitis, and/or terminal osteitis.
- Necrosis may develop when sutures are too tight and not removed in time.

PEARLS

- If the nail plate is to be replaced, it can be soaked in antiseptic solution, which will allow the plate to soften, facilitating the passage of a suture needle to secure it to the nail fold and nail bed. It is also helpful to make a small hole in the plate with an 18-gauge needle or a No. 11 blade, which further assists passage of the suture needle. The suture is ideally passed through the soft tissues first and then through the predrilled nail plate to minimize the risk of a foreign-body granuloma.
- Having the patient don a sterile glove, cutting a hole in the corresponding finger, and rolling the glove tip down may provide an adequate tourniquet effect. This would also provide a sterile field from which to work.
- Use as little suture as possible when repairing a nail bed (more suture, more scarring, less chance of nail adherence to the nail bed).

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UNIT IX

Incision and Drainage Procedures

CHAPTER 33

Abscess Overview and the Use of Sonography

Amanda B. Comer

BACKGROUND

Skin and soft tissue infections (SSTIs) account for more than 6 million ED visits and 14 million ambulatory visits in the United States annually (Breyre & Frazee, 2018). Cutaneous abscesses and cellulitis are the two most common forms of SSTIs, but may be misdiagnosed due to the inability to differentiate one from the other. Although abscesses and cellulitis can be seen simultaneously, they differ in disease process, common causative agent, manifestation, and treatment. Point-of-care ultrasound (POCUS) can augment the clinician's ability to differentiate the two and guide appropriate management.

A *cutaneous abscess* is a collection of pus within the dermis and deeper tissues. A breakdown in the normal epidermal defense mechanism, such as a traumatic breach in the skin, increases the risk for the development of an abscess thus allowing entry of bacteria into the underlying tissue. This event initiates a complex cellular response, mobilizing immune cells to the site of infection. Upon detection of an invading microbe, a proinflammatory response occurs and white blood cells (WBCs) collect with the damaged tissue, forming pus. Pus is a buildup of fluid, damaged or dead tissue, and bacteria. A fibrous capsule forms at the periphery as the abscess progresses. The formation of an abscess wall is the body's mechanism to contain and eliminate a foreign pathogen in an attempt to prevent the bacteria from spreading to surrounding tissue or structures. On occasion, the contents, including bacteria, will escape from the walled-off area, penetrating the bloodstream and surrounding tissue.

Normally found on the skin, *Staphylococcus aureus* is the most common pathogenic culprit leading to a cutaneous abscess. Methicillin-resistant *S. aureus* (MRSA) has been identified as the source of many abscesses as a result of the misuse and overuse of antibiotics. The most frequent sites for cutaneous abscesses are extremities (particularly axilla), groin, external vaginal (Bartholin), tailbone (pilonidal), and areas of hair distribution.

Cellulitis

Cellulitis is an infection of the dermis and subcutaneous tissue of the skin. Management of cellulitis is dependent on its classification as purulent or nonpurulent. Purulent cellulitis is associated with an abscess, drainage, or exudate. Nonpurulent cellulitis has no drainage, exudate, or associated abscess. Symptoms of cellulitis are a result of complex immune and inflammatory reactions. Initially, a bacterial invasion triggers an inflammatory response. Typically, the organism is quickly cleared from the area, but the infiltration of cells, such as Langerhans cells and keratinocytes, release cytokines, interleukin-1, and tumor necrosis factor that enhance skin infiltration by lymphocytes and macrophages. Bacterial invasion may result from breaks in the skin, larger wounds, or preexisting dermatitis. Beta-hemolytic *Streptococcus* (groups A, B, C, G, and F) is the most prevalent causative pathogen of cellulitis.

PATIENT PRESENTATION

Multiple factors contribute to cellulitis/abscess formation, including trauma (abrasions, penetrating wounds, insect bites, injection drug use, skin popping), shaving, restrictive clothing, overgrowth of bacteria, close contact with others with MRSA, immunosuppression (diabetes mellitus, HIV, hemodialysis, cancer), preexisting skin infections (varicella, impetigo, tinea pedis), edema due to impaired lymphatic drainage or venous insufficiency, and skin inflammation (eczema, radiation therapy). A patient with SSTI may present with erythema, swelling, or pain/tenderness. Most abscesses are diagnosed based on these physical exam findings, including the presence of fluctuance and/or pus. When fluctuance is not readily noted, POCUS enables the clinician to identify abscess formation and clarify the location in regard to surrounding structures.

TREATMENT

The Role of Ultrasound in Abscess Treatment

POCUS can support distinction of an abscess versus cellulitis more precisely than assessment alone while guiding appropriate management. Though often seen together, cellulitis and cutaneous abscesses are very different disease processes that appear uniquely different on ultrasound. Assessment of superficial structures can most effectively be accomplished with a high-frequency (5–12 MHz) linear array transducer. Use of color Doppler can support the identification of vessels in close proximity. The abscess may be incised while observing via ultrasound, though this is generally unnecessary. However, this can be particularly useful in cases in which the abscess is near vascular structures. Following completion of incision and drainage, reassessing the abscess with ultrasound is recommended to evaluate for loculated undrained collection of purulence.

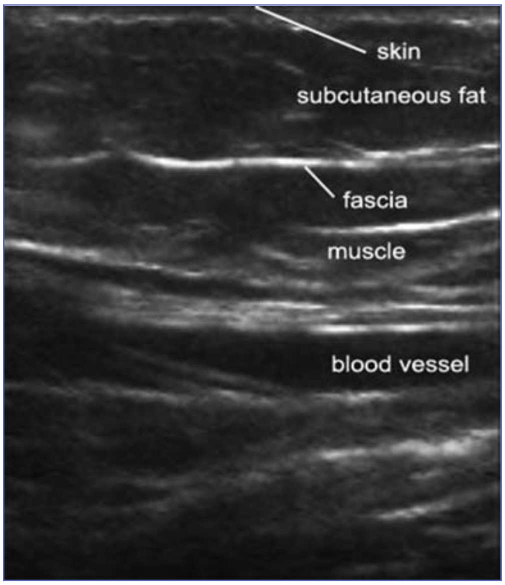


FIGURE 33.1 Tissue layers.

Source: Grimm, L. J., & Carmody, K. A. (2019). Abscess evaluation with bedside ultrasonography. In C. R. Taylor (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/1379916-overview

NORMAL SOFT TISSUE

Tissue layers that can be visualized by ultrasound are the epidermis/dermis, subcutaneous layer, fascia, muscle, and bone (**FIGURE 33.1**). The epidermis and dermis often cannot be differentiated on POCUS and are visualized together as a thin, hyperechoic (*white*) layer. The subcutaneous layer appears as hypoechoic (*black*) fat interspersed with hyperechoic linear echoes running parallel to the skin, representing connective tissue septa. Veins and nerves may also be visualized. Fascia appears as a linear hyperechoic layer with varying thickness depending on the location.

CUTANEOUS ABSCESS

Ultrasound of a cutaneous abscess reveals an anechoic or hypoechoic spherical or oblong collection of echogenic fluid (**FIGURE 33.2**).

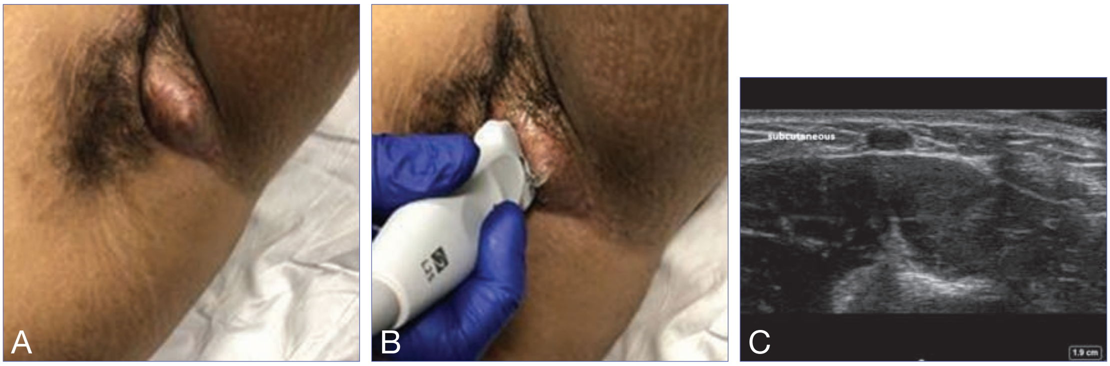


FIGURE 33.2 **A.** Cutaneous abscess axilla. B. Utilizing ultrasound to identify and confirm cutaneous abscess. **C**. Abscess appearance with ultrasound.

Note: The subcutaneous layer appears as hypoechoic (*black*) fat interspersed with hyperechoic linear echoes running parallel to the skin, representing connective tissue septa.

Sources: (A) and (B) Courtesy of Keith Lafferty. (C) Courtesy of Susanna Rudy.

Occasionally, borders may appear poorly defined (**FIGURES 33.3** and **33.4**). Sediment may be seen within the central fluid collection. Gentle compression of the transducer will induce movement or swirling of the abscess content. To distinguish between an abscess and lymph nodes, specifically in the axillary and groin region, this is particularly useful. Lymph nodes will have an echogenic hilum with a darker appearing periphery. Often, a cobblestone appearance of surrounding subcutaneous tissues is visualized on the exam due to associated cellulitis.

FIGURE 33.3 Ultrasound picture of cutaneous abscess.

Source: Courtesy of Tom Costantino.

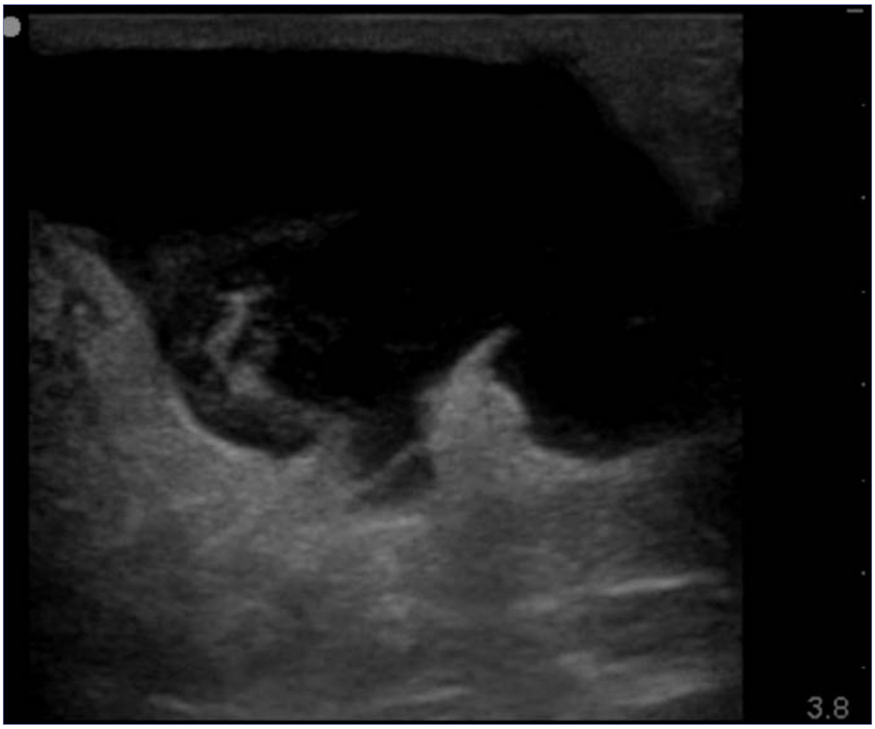
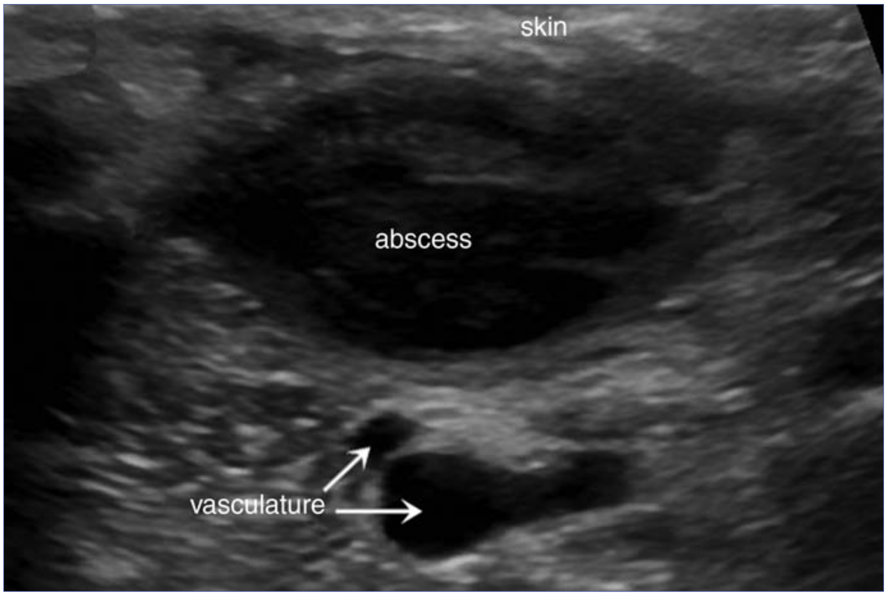


FIGURE 33.4 Ultrasound of subcutaneous abscess.



CELLULITIS

Cellulitis can easily be detected on ultrasound; however, appearance varies by severity. Early cellulitis may appear as generalized swelling and increased echogenicity of the skin and subcutaneous tissues on POCUS (**FIGURE 33.5**). As progression of cellulitis occurs, the amount of subcutaneous fluid increases and hyperechoic fat lobules become separated by hypoechoic fluid-filled areas. The most common and recognizable is the later stage of cellulitis, which has a *cobblestone appearance* (**FIGURE 33.6**).

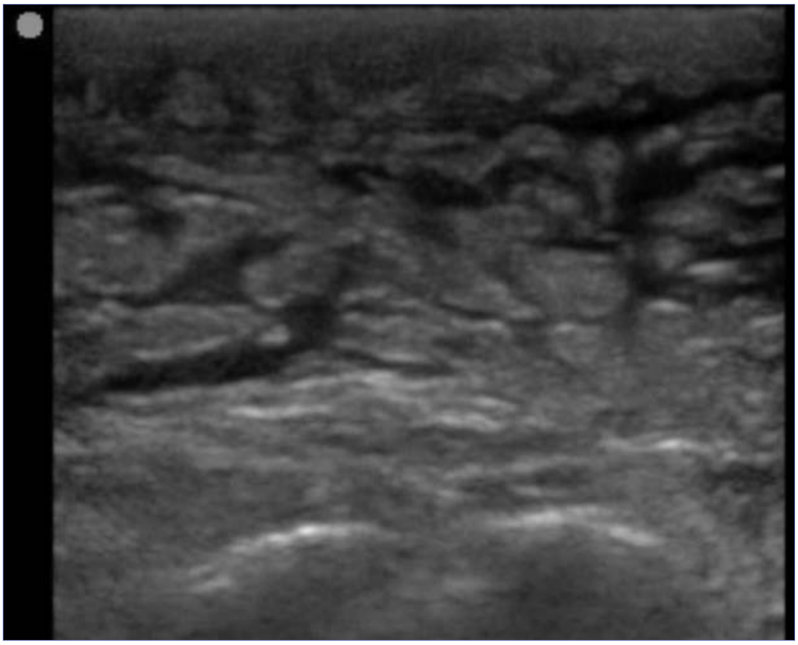


FIGURE 33.5 Ultrasound picture of cellulitis.
Source: Courtesy of Tom Costantino.

FIGURE 33.6 Cobblestone.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

There are no contraindications to the use of ultrasound for evaluating SSTIs; however POCUS may help identify contraindications to incision and drainage (see Chapter 34).

PROCEDURE PREPARATION

A high-frequency (5–12 MHZ) transducer is the best option to use to evaluate soft tissue and allows for higher resolution scanning of superficial structures. If deeper structures need to be evaluated, a curvilinear probe is a good option. Incision and drainage are discussed in Chapter 34.

Equipment Needed

- Protective equipment (gown, gloves, goggles, drape)
- High-frequency linear array transducer with plastic cover and ultrasound machine

PROCEDURE

- Apply personal protective equipment. Fully expose the affected area and place an absorbent pad below the patient.
- Begin scanning a short distance from the affected area to gain an appreciation of the normal anatomy.
- Advance the transducer over the extent of the abscess or cellulitis. Once visualized, rotate the transducer 90 degrees and again advance the probe over the extent of the affected area.
- Using the nondominant hand, place a gloved finger over the point of maximum fluctuance. Move the transducer with its midpoint against the finger. This maneuver helps the clinician correlate the image with the anatomy and gain awareness of an incision site if drainage is needed.
- Note the depth and presence of loculations. Gentle compression of the transducer may induce movement of abscess contents.
- If an ultrasound-guided incision is performed, switch the probe to the nondominant hand and use the well-coordinated hand to hold the sharp instruments. As an alternate, when the abscess is identified and the point of incision is determined, mark it with a pen. Set the ultrasound probe aside and proceed with incision and drainage.

POSTPROCEDURE CONSIDERATION

- Reassess the abscess with POCUS to evaluate for loculated undrained collection of purulence following incision and drainage.

EDUCATIONAL POINTS

- Ultrasound is a useful tool in assisting a clinician's diagnosis of abscess versus cellulitis and guiding appropriate management.
- The use of POCUS can assist in the location and drainage of abscesses, especially in areas with major vessels and organs in close proximity to the affected area.
- POCUS can easily identify surrounding arteries with the use of the Doppler color setting.

PEARLS

- A high-frequency linear transducer is the most useful for soft tissue POCUS.
- Allowing your hand to rest on the patient while holding the transducer provides stabilization and eases controlled movements during the scan.
- Gentle compression of the transducer will induce movement or swirling of the abscess content.

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CHAPTER 34

Incision and Drainage of Cutaneous Abscess

Amanda B. Comer and Theresa M. Campo

BACKGROUND

An abscess can occur on any region of the body, but most frequently presents in the following areas:

- Extremities (specifically axilla)
- Areas of hair distribution (folliculitis, furuncle)
- Neck
- Buttocks

Please review the in-depth discussion of what an abscess is and the use of ultrasonography for identification of an abscess in Chapter 33, Abscess Overview and the Use of Sonography.

PATIENT PRESENTATION

- Red, raised, painful lump
- Warmth
- Firm and/or fluctuant (fluid filled, feels like a ripe piece of fruit)
- Pointing with pustule
- Lymphangitis
- Lymphadenopathy
- Localized or extensive cellulitis
- Fever

TREATMENT

Incision and drainage constitute the definitive treatment for a cutaneous abscess. Any abscess with pus formation, whether firm or fluctuant, should be incised and drained. Antibiotic treatment alone does not adequately treat loculated collections of pus and infection. Although needle aspiration is insufficient to adequately drain an abscess, it can be useful in cosmetically sensitive areas such as the face. In patients with noncomplicated small cutaneous abscesses in which spontaneous drainage occurs, close observation for resolution may be appropriate. Abscesses less than 5 mm can be treated effectively with warm compresses based on the severity and location of the infection. For small abscesses treated with warm compresses, antibiotics are indicated in immunocompromised patients or for abscesses associated with cellulitis.

Incision and drainage is a common procedure that can safely be performed in various settings. Incisions should be liberal to allow for breakup of loculations and appropriate drainage of the purulent material. Accompanying cellulitis should be treated empirically based on the common organisms found in the region (i.e., methicillin-resistant *Staphylococcus aureus* [MRSA]). Cultures should be obtained to determine the offending organism(s). Modifications to treatment can be made once culture results are reported.

All abscesses should be evaluated and treated with careful consideration given to the patient's past and current medical history, family history, and current trends of bacterial organism invasion in the treatment area. Surgical referral should be considered in abscesses with high risk for complications, such as hand or breast abscesses, and those that are challenging due to location (adjacent to large blood vessels). Abscesses that are deep seated or that occur over major vessels can be investigated further using ultrasonography (discussed in Chapter 33, Abscess Overview and the Use of Sonography).

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Abscesses that lie in close proximity to a major vessel may require specialty consultation.
    - Location and nature of abscess should be evaluated with point-of-care ultrasound prior to the procedure.
- Hand abscesses involving the palmar aspect and with passive range-of-motion pain should be referred immediately to a hand specialist for evaluation and treatment.
    - Increased severity of infection occurs because the flexor tendon has a sheath of synovial fluid and the extensor tendon does not.

SPECIAL CONSIDERATIONS

- Pediatric patients may require conscious sedation for deep-seated or difficult-to-manage areas due to movement or abscess severity
- General anesthesia may be required for abscesses located in the perirectal, supralevator, ischiorectal areas, and those that are deep seated or in the area of major vessels or over bony prominences
- Abscesses located in the palmar aspect of the hand should be referred to a hand specialist to avoid tendon injury or neurovascular compromise
- Abscesses located on the face, particularly the nasolabial fold, may drain into the sphenoid sinus, causing cavernous sinus thrombosis
- Immunocompromised patients and those with comorbidities
    - Abscesses in patients with organ transplant, HIV, AIDS, diabetes, and/or cancer should be treated more aggressively and with a lower index of suspicion for abscess and infection.
    - Patients with immunosuppression may not present with classic signs and symptoms of abscess formation as they may lack the host defense and release of cytokines needed to produce the inflammatory reaction. They may present only with a low-grade fever or malaise. Atypical bacterial organisms and fungus are more common in this population.
- Intravenous (IV) drug users
    - Patients with multiple abscesses or abscesses on the arms and antecubital fossa or dorsal aspect of the hand should be questioned for IV drug use, and treated more aggressively for atypical organisms and fungus.
- Pregnanct patients
    - Patients who are pregnant should be treated with antibiotics that are considered safe in pregnancy if indicated.
- Patients with artificial heart valves and prosthetic joints
    - Prophylaxis is based on the current American Heart Association/American College of Cardiology guidelines.
    - The timing of the procedure may need to be reconsidered to help prevent endocarditis in this group of patients.
    - Consultation with a specialist is recommended.

PROCEDURE PREPARATION

- Protective gown, gloves, goggles, and drape
- Skin cleanser (povidone-iodine, chlorhexidine solution)
- Local anesthetic (lidocaine 1% or 2%, bupivacaine—longer duration of action)
- 20- or 35-mL syringe for irrigation with splash guard if available
- 10-mL syringe
- 25-gauge needle for injection of lidocaine
- No. 11 or No. 15 scalpel blade with handle
- Curved hemostat
- Scissors
- Culture swab

- Normal saline solution
- Plain or iodoform gauze: ¼, ½, or 1 inch depending upon the size and depth of the abscess
- Gauze pads
- Kling or gauze for wrapping
- Tape

PROCEDURE

- Obtain informed consent.
- Identify and confirm the location of the abscess. This can be done utilizing point-of-care ultrasound (POCUS) when available, to identify the location of the abscess.
- Cleanse the skin using a circular motion, moving from the center (inner most point) outward to free debris and bacteria.
- Place an absorbent protective pad under the treatment area.
- Drape the patient to maintain a clean area as well as to protect the patient's privacy.
- Strict sterile technique is not required for this procedure. In this era of resistance, however, it should be used whenever possible.

Infiltration

- Anesthetize the region, inserting a 25-gauge needle at the dome of the abscess. The needle should be parallel to the surface of the skin.
- Inject the anesthetic gently into the intradermal layer, until the area is large enough for incision (**FIGURE 34.1**).
- Blanching will occur as the anesthetic spreads.

Incision

- With attention to the skin tension line, make a liberal incision with a No. 11 or No. 15 scalpel over the center of the abscess. Cut with intent through the skin and into the cavity of the abscess using firm, direct pressure (**FIGURE 34.2**). The most common cause of abscess reoccurrence is inadequate drainage or an incision that is not large enough.

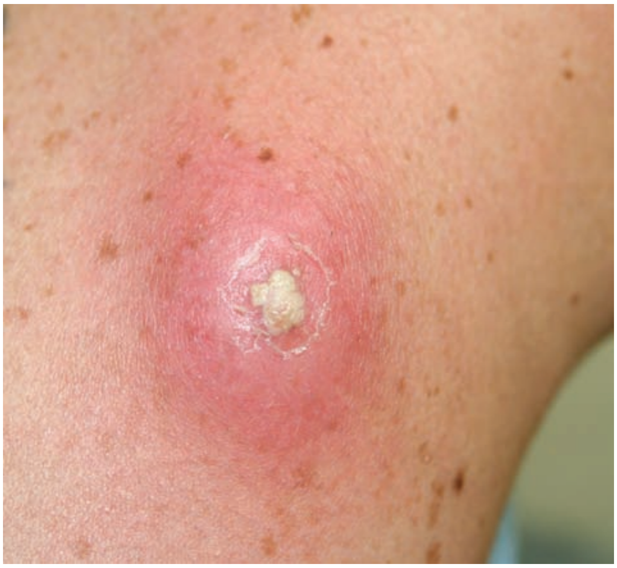

FIGURE 34.1 Abscess.

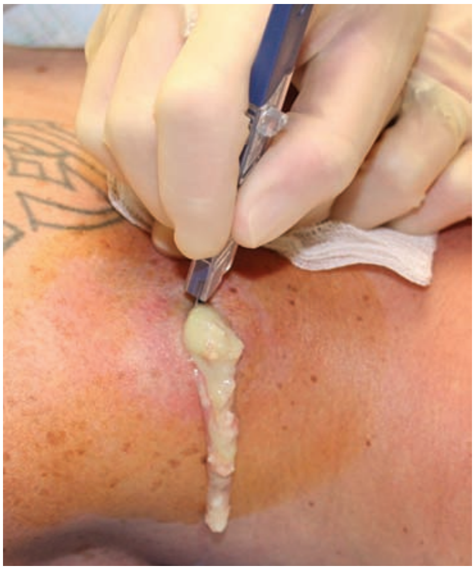

FIGURE 34.2 Incising an abscess.

- Do not puncture through the back border of the abscess wall, as this can result in excessive bleeding.
- Apply pressure to the area and allow the pus to drain.
- If there is little drainage, consider lengthening/widening the incision.
- Swab the *inside* of the abscess—not the drainage—with a culture swab (**FIGURE 34.3**).
- To assist the breaking of loculations, use a curved hemostat to perform a blunt dissection (**FIGURE 34.4**). Do *not* place your finger or any sharp object inside the wound.
- Irrigate the abscess liberally with normal saline, taking care to prevent splashing onto the clinician (**FIGURE 34.5**).
- Carefully insert iodoform or plain packing gauze into the cavity as needed (**FIGURE 34.6**). Avoid overpacking, which can lead to pressure necrosis of the surrounding tissues. The goal is to keep the incision open, allowing for continued drainage of the wound.
- Apply a liberal amount of gauze dressing to absorb continued draining.
- Tetanus immunization should be up to date.
- Abscesses should not be sutured closed.

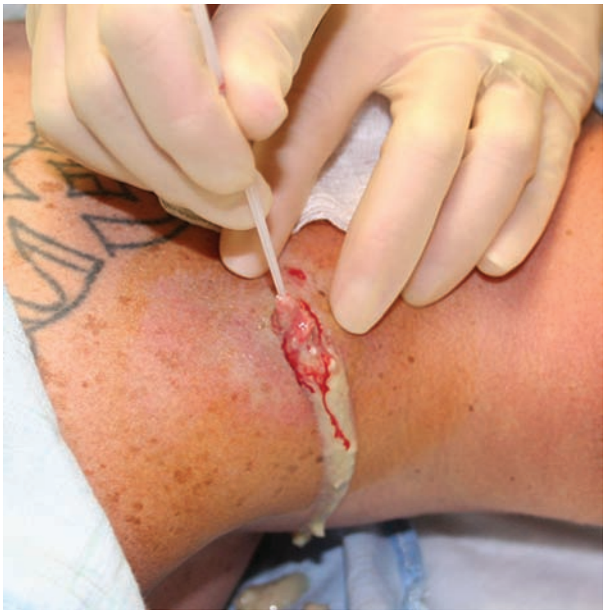

FIGURE 34.3 Obtaining a culture swab.

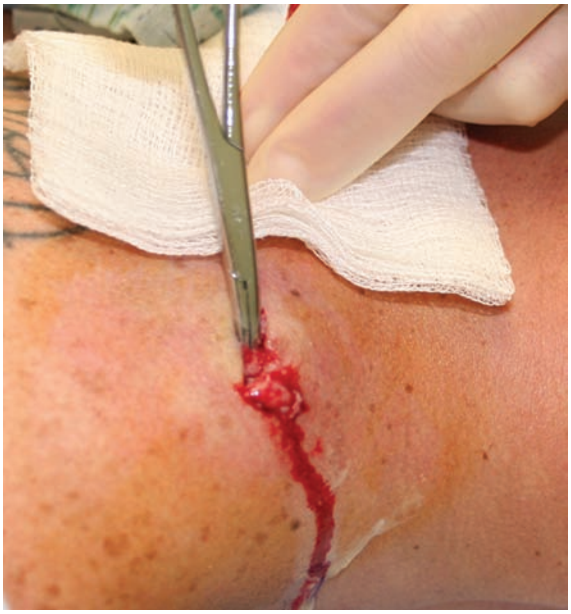

FIGURE 34.4 Blunt dissection.

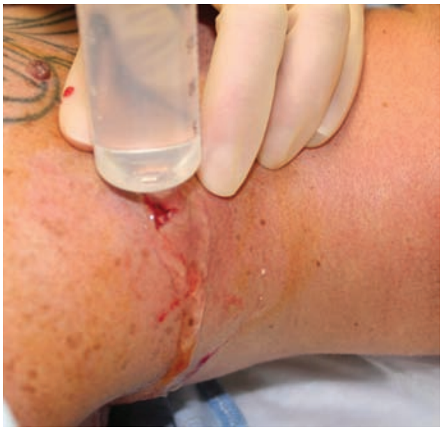

FIGURE 34.5 Irrigation of an abscess cavity.

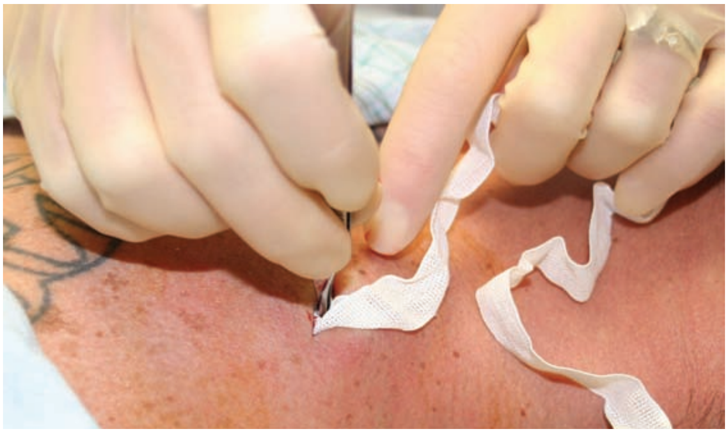

FIGURE 34.6 Insertion of packing.

ULTRASOUND GUIDANCE

Ultrasound has been shown to aid in the diagnosis of abscesses as well as in assisting in discriminating between abscess and cellulitis. Ultrasound can also show relationship to nearby anatomic structures such as major blood vessels which can assist in drainage.

POSTPROCEDURE CONSIDERATIONS

Pain

The contents of abscesses are acidic and therefore can affect the efficacy of the anesthetic. Performing a field block and administering oral or intravenous (IV) pain medicine can help reduce the pain.

Antibiotic Therapy

Successful incision and drainage of abscesses does not require antibiotic therapy in healthy individuals unless the abscess is accompanied by cellulitis. However, patients who are immunocompromised, diabetic, or IV drug users should be considered for antibiotic treatment.

EDUCATIONAL POINTS

- Repeat evaluation and remove packing within 48 hours of the procedure.
- Stress the importance of follow-up.
- Delineate the risks and benefits of antibiotic use and pain medicine.
- Area should not get wet until packing is removed.
- Healing occurs through tissue granulation from the base of the wound.
- Proper hygiene and handwashing are effective against recurrence and spread of infection.

COMPLICATIONS

- Infection that progresses to surrounding tissue causing cellulitis, lymphangitis, and/or fever should be treated with antibiotic therapy.
- Recurrence of the abscess necessitates consideration of risk factors or abnormalities, including presence of a foreign body, cancer, *Staphylococcus* colonization, and immunologic disorders.

PEARLS

- Fluctuance can be described to patients as a piece of ripe or overripe fruit, such as a peach.
- Premedicating with oral analgesia helps to make the procedure more tolerable.
- Peripads can be used for abscesses in the groin or buttocks or areas that are difficult to dress with tape or wrapping gauze.
- Patients presenting with pus should not leave until it is drained.

RESOURCES

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CHAPTER

35

Procedures for Managing Pilonidal Cyst/Abscess

Wesley D. Davis and Theresa M. Campo

BACKGROUND

Pilonidal disease affects the skin and subcutaneous tissues surrounding the natal cleft of the buttocks. Contemporary theories suggest that pilonidal disease is acquired rather than congenital. The specific way in which pilonidal cysts and abscesses form is unclear but is likely due to inflammation in the natal cleft. It is postulated that pilonidal cysts and abscesses begin from repetitive microtrauma to the area and by bacteria entering the hair follicles. Microtrauma causes the epithelium to line the cavity, which in turn causes an occlusion that prevents drainage. Hair follicle enlargement then causes an inflammatory response and edema. The increased pressure causes the spreading of purulent material to the surrounding subcutaneous tissue, thus promoting abscess formation. These abscesses can be quite large and are found in the gluteal fold overlying the coccyx (see **FIGURE 35.1**).

While anaerobic and aerobic organisms may cause pilonidal abscesses, the most common organism isolated in cultures is *Staphylococcus aureus.* Pilonidal disease is more prevalent in men than in women and has a mean age at presentation of 20 years. Other risk factors include obesity, repetitive local trauma and irritation, prolonged sitting, family history, and increased hair density in the natal cleft region.

Ultrasonography of soft tissues can assist with the diagnosis of pilonidal cyst and abscess that is amenable to incision and drainage. The high-frequency linear probe is the best probe to use to scan the superficial tissues of the natal cleft area. By ultrasound, the cyst or abscess will appear as a complex fluid-filled mass near the sacrum. Inflammation of the surrounding tissues causes increased blood flow to the area of the cyst or abscess, which may be visualized as vascular flow with Doppler evaluation. The area should be inspected in both the transverse and sagittal planes and include measurements of depth, width, and length.

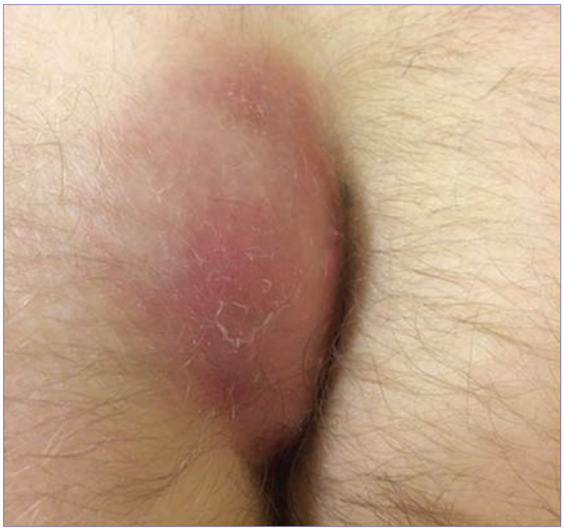

FIGURE 35.1 Pilonidal abscess.
Source: Courtesy of Jonathanlund.

PATIENT PRESENTATION

- Sinus tract or “pit” in the sacrococcygeal region
- Tenderness to palpation
- Pain in the intergluteal region
- Fluctuant mass
- Warmth and erythema

- Purulent and/or bloody discharge
- Localized or extensive cellulitis
- Fever and malaise

TREATMENT

The goal of treatment for pilonidal abscess is to fully remove the internalized material (i.e., hair, keratin, and purulent cellular debris). Simple incision and drainage can be performed to treat the acute fluctuant abscess until surgical excision of the internalized material can be done. Pilonidal abscesses have a varied recurrence rate, which can be as high as 90%. Even with surgical excision, 20% to 40% may recur. A flared-end de Pezzer catheter may be used for an extended period of time to allow for granulation and closure of chronic sinus. Simple incision and drainage of pilonidal abscess will be the focus of this chapter.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Immunocompromised patients (relative)

SPECIAL CONSIDERATIONS

- Immunocompromised patients
- Diabetes
- Cancer
- HIV-positive patient
- Pregnancy
- Pediatric and elderly patients
- Comorbidities
- Prosthetic heart valves
- Prosthetic joints

PROCEDURE PREPARATION

- Protective gown, gloves, and goggles—abscess contents may be under pressure
- Drape
- Skin cleanser
- Lidocaine 1% or 2% with epinephrine (bupivacaine is another option because of its longer duration of action)
- 20- or 35-mL syringe for irrigation
- 10-mL syringe
- 25-gauge needle for injection of lidocaine
- No. 11 or No. 15 scalpel blade with handle
- Hemostat and scissors
- Culture swab
- Normal saline solution
- Suture kit
- Plain or iodoform gauze: ¼, ½, or 1 inch, depending upon the size and depth of the abscess
- Gauze pads
- Kling or gauze for wrapping
- Tape

PROCEDURE

- Cleanse the skin with povidone-iodine or another antiseptic solution using a circular motion to remove debris and bacteria.
- Place an absorbent protective pad under the treatment area.
- Drape the patient to maintain a clean area as well as to protect the patient's privacy.

- Strict sterile technique is not required for this procedure. However, because of the increasing prevalence of bacterial resistance, sterile technique should be used whenever possible.

NOTE Figures illustrating the following procedural steps appear in Chapter 34, Incision and Drainage of Cutaneous Abscess.

Infiltration

- Anesthetize the top of the wound by inserting a 25-gauge needle just under and parallel to the surface of the skin.
- Inject the anesthetic gently into the intradermal layer, until the area is large enough for incision.
- You will notice blanching of the skin.

Incision and Drainage

- Make a liberal incision directly over the area of maximum fluctuance with a No. 11 or No. 15 scalpel, making sure to cut through the skin and into the cavity of the abscess.
- Direct, firm pressure should be used when making the incision.
- Be careful not to puncture through the back end of the abscess wall because this can cause excessive bleeding.
- Extend the incision to allow for adequate drainage of pus and enough room for wound dissection.
- Attention should be given to the skin tension lines; these should be followed whenever possible for the best cosmetic outcome.
- Allow the pus to drain freely and apply pressure to the area to assist with expression of pus and abscess contents.
- With a culture swab, swab the inside of the abscess—not the drainage (see Chapter 34, Incision and Drainage of Cutaneous Abscess).
- Perform a blunt dissection with a curved hemostat using a circular motion to break up loculations.
- Never probe the abscess with a gloved finger, especially when a foreign body is suspected.
- Irrigate the abscess liberally with normal saline.
- Loosely pack iodoform or plain packing into the cavity.
- Place a sufficient amount of packing into the cavity, making certain not to overpack the wound thereby causing pressure necrosis, which causes ischemia and death to the surrounding tissue.
- Apply a gauze dressing to help collect any drainage.
- Abscesses should not be sutured closed.

POSTPROCEDURE CONSIDERATIONS

Immunizations

- Tetanus immunization should be up to date.

Pain

- The contents of the abscess are acidic and can decrease the efficacy of the anesthetic.
- Performing a field block and administering oral pain medicine can help reduce the pain.

Drainage

- If there is little or no drainage from the abscess, consider a deeper and/or wider incision.
- If sebaceous material is extracted from the site and there is little or no pus, proceed with the procedure as described previously.

Antibiotic Therapy

- Antibiotic therapy is not warranted in healthy individuals unless the abscess is accompanied by cellulitis.
- Patients with a history of methicillin-resistant *Staphylococcus aureus* (MRSA), underlying immunosuprression, diabetes, another concurrent systemic illness, or a history of intravenous drug use should be considered for antibiotic treatment along with incision and drainage.

EDUCATIONAL POINTS

- Packing should be changed if persistent drainage is present; otherwise, removal within 48 hours of placement is recommended during follow-up with a clinician.
- Stress the importance of follow-up.
- Weigh the risks and benefits of antibiotics and pain medicine.
- Area should not get wet until the packing is removed.
- Healing occurs through tissue granulation from the base of the wound.
- Proper hygiene and handwashing are effective against recurrence and spread of infection.
- The use of a donut pillow will help to reduce the pressure on the affected area.

COMPLICATIONS

- Progression of infection to surrounding tissue causing cellulitis, lymphangitis, and/or fever should be treated with antibiotic therapy.
- Recurrence rates of pilonidal abscess are approximately 40%, which necessitates consideration of risk factors or abnormalities, including foreign body, cancer, *Staphylococcus* colonization, and immunologic disorders.

PEARLS

- Instruct patients who have sitting occupations to take frequent breaks or use donut pillows to reduce the pressure on the coccyx area.
- Do not forget to medicate for pain, as this can be a painful experience.

RESOURCES

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CHAPTER 36

Procedures for Managing Bartholin Abscess

Wesley D. Davis and Theresa M. Campo

BACKGROUND

Normally, the Bartholin gland is a nonpalpable secretory organ approximately the size of a pea. It is located at the posterior introitus bilaterally at 5 and 7 o'clock in the vulvovaginal area. Each gland drains through an approximately 2-cm long duct that empties into the vaginal vestibule. The gland maintains the moisture of the vaginal mucosa. Obstruction of the duct may result in the formation of a cyst or abscess when there is retention of secretions, which causes the duct to dilate. A Bartholin abscess can be a common problem in women of reproductive age. Patients with a first Bartholin gland abscess after the age of 40 should be referred to gynecology to rule out Bartholin gland carcinoma. An abscess is distinguishable from a cyst in that an abscess produces a rapid onset of swelling and pain in the vulvar area. Cysts are often asymptomatic in nature. **FIGURE 36.1** shows a Bartholin gland abscess.

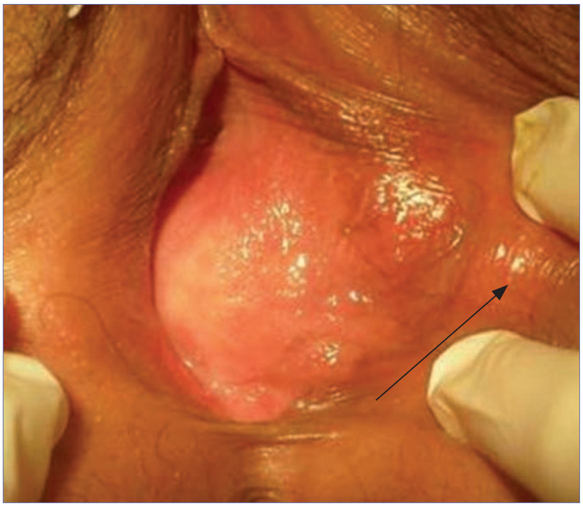

FIGURE 36.1 Bartholin abscess.

Most Common Causative Organisms

AEROBIC

- *Neisseria gonorrhoeae*
- *Staphylococcus aureus*
- *Streptococcus faecalis*
- *Escherichia coli*
- *Pseudomonas aeruginosa*
- *Chlamydia trachomatis*

ANAEROBIC

- *Bacteroides fragilis*
- *Clostridium perfringens*
- *Peptostreptococcus* species
- *Fusobacterium* species

PATIENT PRESENTATION

- Acute unilateral swelling of labia minora
- Pain with walking and sitting
- Exquisitely tender mass—grape size
- Dyspareunia—painful intercourse
- Fluctuant
- Erythema
- Spontaneous rupture with purulent drainage
- Localized cellulitis
- Systemic infection not common with this type of abscess

TREATMENT

To prevent recurrence, simple incision and drainage with Word-catheter placement is the recommended first-line treatment of a Bartholin's gland abscess. If a Word catheter is not available, an 8-French pediatric Foley catheter or gauze packing may be substituted. A Bartholin's gland abscess drained without subsequent Word-catheter placement has a much higher rate of recurrence. Removal of the gland or marsupialization may be performed if recurrence is an issue, but is not often considered for initial treatment. The goal of treatment is drainage of the abscess contents, prevention of fluid reaccumulation, and pain relief. Bartholin abscesses are painful, and patient comfort during the incision and drainage should be a priority.

Antibiotics may be needed if there are signs of cellulitis in the surrounding tissue. Antibiotics with polymicrobial coverage, such as trimethoprim–sulfamethoxazole or amoxicillin–clavulanate, are suitable for outpatient therapy. Cultures to screen for *N gonorrhoeae*, *C trachomatis*, and other sexually transmitted diseases (STDs) should be considered depending on the patient's risk factors. Tetanus immunization status should be updated if necessary.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Complex or recurrent abscesses may require general anesthesia for removal of the Bartholin gland.

SPECIAL CONSIDERATIONS

- Immunocompromised patients
- Diabetes
- Cancer
- HIV-positive patients
- Pregnancy

PROCEDURE PREPARATION

- Protective gown, gloves, and goggles—abscess contents may be under pressure
- Absorbent pad
- Drape
- Skin cleanser
- Lidocaine 1% (bupivacaine is another option because of its longer duration of action)
- 20- or 35-mL syringe for irrigation
- 10-mL syringe
- 25-gauge needle for injection of lidocaine
- No. 11 scalpel blade with handle
- Hemostat, scissors
- Culture swab
- Normal saline solution
- Plain or iodoform gauze: ¼, ½, or 1 inch, depending on the size and depth of abscess
- Peri-pad
- Word catheter, 8-French pediatric Foley, or plain packing

PROCEDURE

- Place an absorbent protective pad under the treatment area.
- Place the patient in the lithotomy position.
- Drape the patient to maintain a clean area as well as to protect the patient’s privacy.
- Strict sterile technique is not required for this procedure. However, because of the era of resistance, sterile technique should be used whenever possible.

Infiltration

- Cleanse the skin with povidone-iodine or another antiseptic solution using a circular motion to remove debris and bacteria.
- Apply a topical analgesic to the mucosal surface for 10 minutes where the incision will be made.
- Insert a 25- or 27-gauge needle into the subcutaneous layer of the labia minora just under the mucosa.
- Infiltrate the area with a local anesthetic, such as lidocaine 1% (1–3 mL).

Incision and Drainage

- Make a 0.5-cm incision along the medial mucosa at or behind the hymenal ring, not the skin, with a No. 11 scalpel.
- Use the tip of the scalpel or a hemostat to puncture the abscess cavity.
- Make an incision that is large enough to allow for proper drainage of fluid contents (**FIGURE 36.2**).
- Be careful not to puncture through the back end of the abscess wall, as this can cause excessive bleeding.
- Allow the pus to drain freely; apply pressure to the area to assist with expression of pus and abscess contents.
- With a culture swab, swab the inside of the abscess, not the drainage.
- A curved hemostat moved in a circular motion can be used to break up remaining loculations. Never place a gloved finger inside the abscess, especially when a foreign body is suspected.
- Irrigate the abscess with normal saline.
- Insert a Word catheter, Foley catheter, or iodoform gauze or plain packing into the cavity.
- Place a sufficient amount of packing into the cavity. Use caution to not overpack the wound causing pressure necrosis, which leads to ischemia and death to the surrounding tissue.

Insertion of a Word Catheter

- Make an incision large enough to fit the deflated Word catheter but small enough to hold the inflated balloon of the catheter in place.
- Quickly insert the deflated catheter into the cavity while the abscess is draining as the cavity may collapse and catheter insertion may not be achievable (**FIGURE 36.3**).

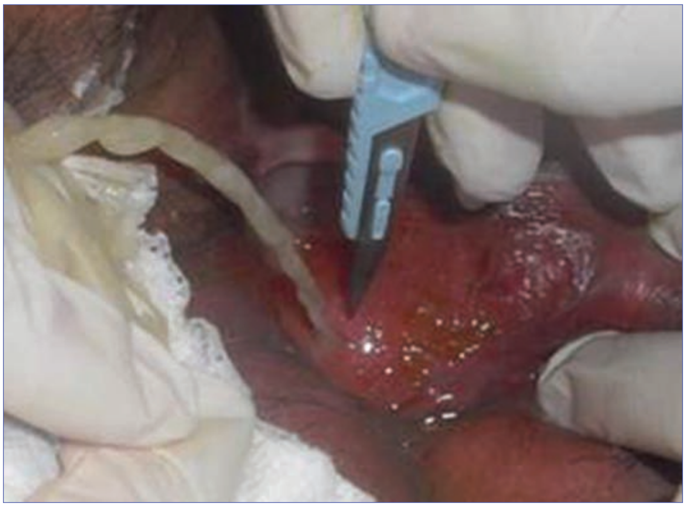

FIGURE 36.2 Incising a Bartholin abscess.

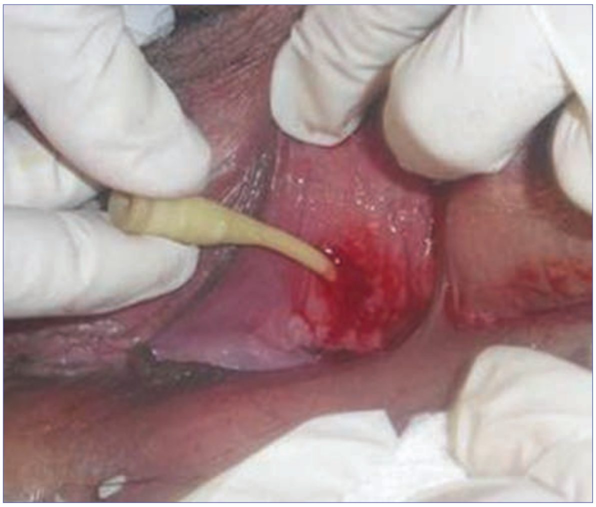

FIGURE 36.3 Insertion of Word catheter.

- Using a 25-gauge needle, instill 2- to 4-mL of water into the stopper.
- Place the free end of the catheter into the vagina.
- The catheter should remain in place for 2 to 4 weeks.
- Apply a gauze dressing to help collect any drainage.
- Abscesses should not be sutured closed.

POSTPROCEDURE CONSIDERATIONS

Incising the Abscess

- Failure to obtain pus or to feel a "pop" after the small incision is made in the mucosa and the cavity has been punctured may indicate a failed procedure.
- "Skewer" the abscess onto a hemostat by stabilizing the abscess between the thumb and index finger first.

Persistent Pain

- This can occur if too much fluid accumulates after packing or insertion of a Word catheter.
- Make a larger incision to facilitate proper drainage, then reinsert packing.
- Consider specialty referral for the marsupialization procedure.

Word Catheter Falls Out

- For an incision too big to hold the catheter in place, consider using packing.
- Word-catheter reinsertion can be performed if it falls out before the 2- to 4-week time period.

EDUCATIONAL POINTS

- Packing should be changed if persistent drainage is present; otherwise, removal within 48 hours of placement is recommended during follow-up with a clinician.
- Stress the importance of follow-up.
- Explain the risks and benefits of antibiotics and pain medicine.
- Area should not get wet until the packing is removed.
- Area can get wet if a Word catheter is inserted.
- Word catheter should ideally remain in place for 2 to 4 weeks but may fall out within 1 week.
- Sexual intercourse is not contraindicated with a Word-catheter insertion.

COMPLICATIONS

- Bleeding
- Progressive infection, cellulitis, and sepsis
- Recurrence

PEARLS

- Do not forget to medicate for pain, as this can be a painful experience.
- Use a peri-pad to protect clothing from drainage.
- Alert patients of the foul odor that may emanate from the abscess once it is incised. Use peppermint oil or air freshener before the procedure.
- Placing a fracture bedpan under the patient's buttocks will assist in drainage accumulation. Some abscesses drain a lot of fluid and patients would not want to lie in it.

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UNIT X

Procedures for Examination and Management of Common Eye Injuries

CHAPTER

37

Eye Examination

Mary Haynes

BACKGROUND

The key to any examination is to perform each element systematically. Before conducting an eye exam, obtain a pertinent ophthalmologic history, including the use of corrective glasses or lenses, previous eye surgeries, or any ophthalmologic medication use. If a chemical injury is suspected to the eye, copious irrigation with water or saline is the priority; additional examination should occur only after irrigation.

PATIENT PRESENTATION

When a patient presents with an eye complaint, ask the following questions:

- Is there any eye pain?
- Has there been recent surgery or trauma?
- Are there any systemic symptoms?
- Is there any foreign-body sensation?
- Has there been any chemical exposure?
- Is there any history of systemic autoimmune disease?
- Have there been any similar previous episodes?

GENERAL EYE EXAM

Knowing the anatomy of the eye is necessary when performing an assessment (**FIGURE 37.1**).

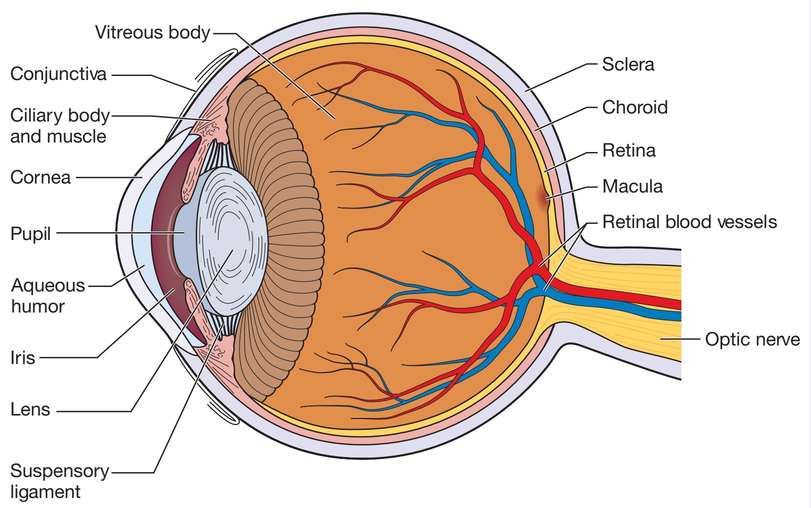
Vitreous body
Conjunctiva
Ciliary body and muscle
Cornea
Pupil
Aqueous humor
Iris
Lens
Suspensory ligament
Sclera
Choroid
Retina
Macula
Retinal blood vessels
Optic nerve

FIGURE 37.1 Anatomical illustration of the eye.

Source: Reproduced from Myrick K. M., & Karosas, L. (Eds.). (2021). *Advanced health assessment and differential diagnosis: Essentials* for clinical practice. New York, NY: Springer Publishing Company.

Visual Acuity

Visual acuity is the vital sign of the eye, and corrected vision should always be documented. This is typically performed with a wall-mounted Snellen chart (**FIGURE 37.2**); however, acuity can also be tested using a Rosenbaum chart (a near card) that is held 14 inches from the patient. For those patients who do not have their corrective lenses available, consider using a pinhole reader. For severely impaired vision, finger counting and/or light perception are also acceptable. Children and/or illiterate patients may be tested using the Allen chart (**FIGURE 37.3**). Alterations in visual acuity may be caused by myopia, hyperopia, foreign body, abrasion, injury, or macular or retinal changes.

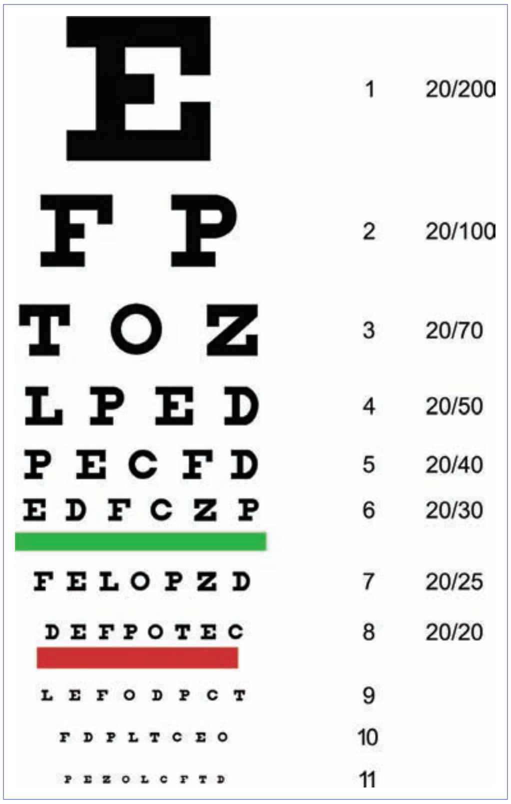
E 1 20/200
F P 2 20/100
T O Z 3 20/70
L P E D 4 20/50
P E C F D 5 20/40
E D F C Z P 6 20/30
F E L O P Z D 7 20/25
D E F P O T E C 8 20/20
L E F O D P C T 9
F D P L T C E O 10
P E Z O L C F T D 11

FIGURE 37.2 Snellen chart.

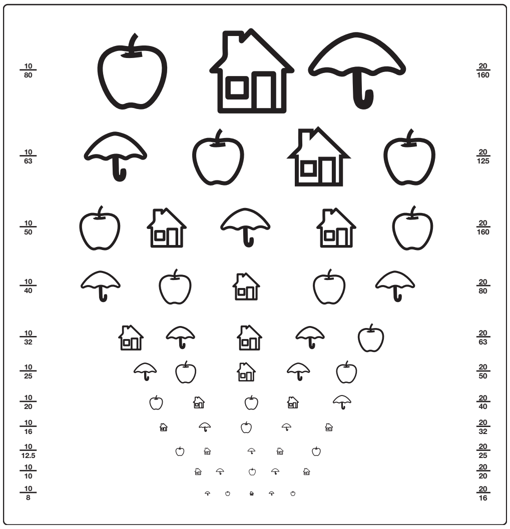
10/80 20/160
10/63 20/125
10/50 20/160
10/40 20/80
10/32 20/63
10/25 20/50
10/20 20/40
10/16 20/32
10/12.5 20/25
10/10 20/20
10/8 20/16

FIGURE 37.3 Allen chart.

Source: Reproduced from Gawlik, K., Mazurek Melnyk, B., & Teall, A. M. (Eds.). (2021). *Evidence-based physical examination: Best practices for health and well-being assessment.* New York, NY: Springer Publishing Company.

Confrontational Visual Fields

To perform this assessment correctly, the clinician should test each eye separately. The patient should cover one eye and look at the examiner's nose. The examiner should place their fingers halfway between themselves and the patient and wiggle the fingers while moving them medially toward the patient. For example, if the left eye is being tested for confrontational visual fields, the right eye will be covered; the examiner will use their left hand and wiggle their fingers as they move their hand medially toward the right side of the patient's body. A patient should see the fingers at roughly the same time as the examiner. This should be done in each visual quadrant for each eye. The examiner will have to switch the hand covering their own eye to test the medial and lateral visual fields. Deficits may indicate conditions such as glaucoma, stroke, hypertension, diabetes, multiple sclerosis, and so forth.

Extraocular Movements

To test the muscles of the eye, have the patients look in the six cardinal positions of gaze. Extraocular muscles are innervated by cranial nerves III, IV, and VI (**FIGURE 37.4**). The examiner should keep in mind that cranial nerve palsies or paresis may be caused by stroke, diabetes, hypertension (HTN), infections, and other etiologies.

Contraindications: Examining extraocular movement (EOM) is contraindicated if a globe rupture is suspected.

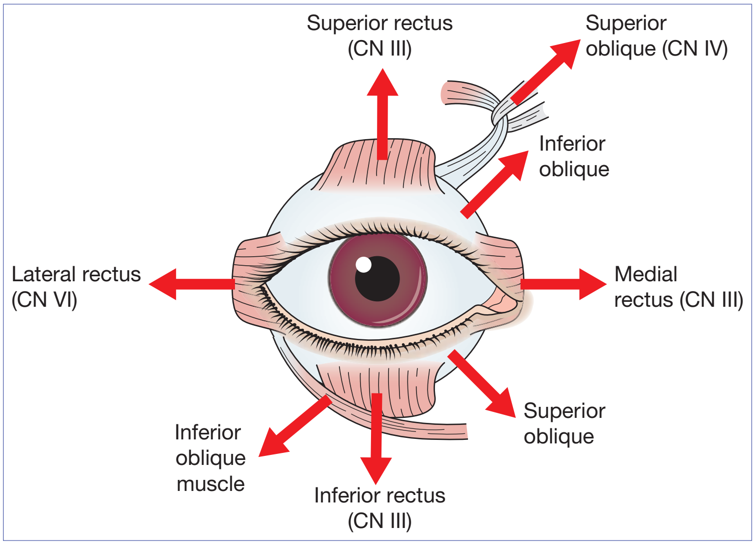

FIGURE 37.4 Six cardinal positions of gaze, cranial nerve innervation, and ocular muscles.

Source: Reproduced from Myrick, K. M., & Karosas, L. (Eds.). (2021). *Advanced health assessment and differential diagnosis: Essentials for clinical practice*. New York, NY: Springer Publishing Company.

Pupils

Note the size, shape, symmetry, and reactivity of the pupils. A classic teardrop-shaped pupil may be indicative of trauma or even a globe rupture. Anisocoria, pupillary size difference, may be a normal or chronic finding for some patients. The examiner should also test the pupils for afferent pupillary defect (APD) by the swinging-flashlight test. In this test, the examiner should shine a bright light in each eye separately. To test the first eye, the examiner should shine a bright beam of light at the pupil for approximately 3 seconds. The examiner will note whether the pupil of the eye that is being tested constricts to the light. In addition, the examiner should note whether the opposite eye constricts to that beam of light. The examiner should then repeat the same test on the other side. In a normal swinging-flashlight test, the pupils of both eyes should constrict equally. If APD is present, there will be less constriction in the eye with a retinal or optic nerve disease.

External Exam

Inspect and palpate the ocular eyelid and surrounding structures for drainage (crusting on lashes or lid margins), crepitus, swelling, trauma, or lacerations. Any laceration to the medial third of the lid increases the risk of injury to the lacrimal duct and should be repaired by an ophthalmologist. If a foreign body is suspected, the lids should be everted to inspect using a cotton applicator or using a lid retractor (**FIGURE 37.5**). Examine behind each lid and deep into the corners.

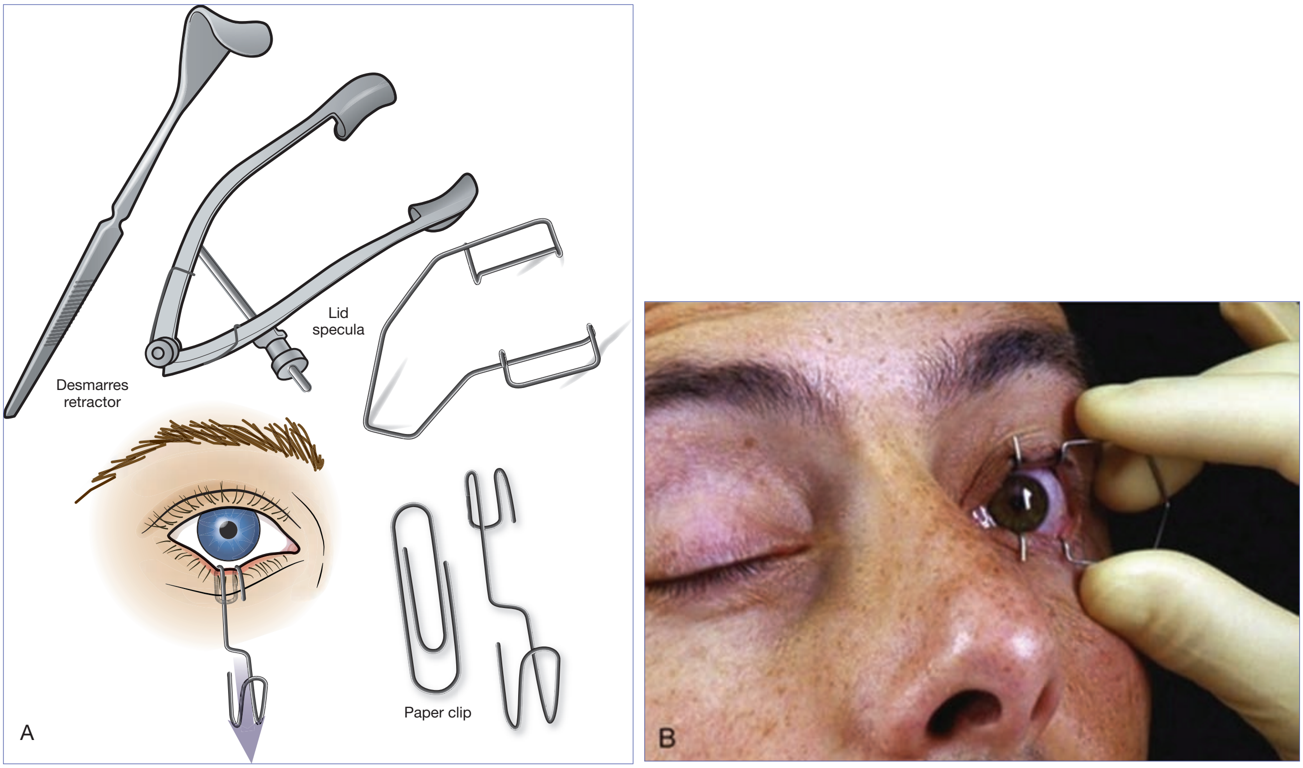

FIGURE 37.5 Lid retractors.
(A) A Desmarres retractor, lid specula, or retractor improvised from a paper clip allows active manipulation of the lids. Free-standing specula may require a VIIth nerve block to reduce the blepharospasm. (B) Lid retractor in place.

Source: (B) Reproduced with permission from Fogle, J. A., & Spyker, D. A. (1990). Management of chemical and drug injury to the eye. In L. M. Haddad & J. F. Winchester (Eds.), *Clinical management of poisoning and drug overdose* (2nd ed.). Philadelphia, PA: Saunders. Retrieved from https://clinicalgate.com/ophthalmologic-procedures

Sclera, Conjunctiva, and Cornea

These structures form the surface of the globe. The sclera is the "white portion of the eye" that surrounds the cornea. Normal sclera should appear white; however, at times, the sclera may be reddened, which is referred to as *scleral injection*, or, in liver disorders, the sclera may appear yellow, which is referred to as *icterus*. The conjunctiva is the vascular covering of the inside of the eyelids. The conjunctiva should be inspected for discharge, chemosis, lacerations, subconjunctival hemorrhage, and so on. The cornea is a transparent membrane that covers the iris, pupil, and anterior chamber and allows light to enter the eye; it also serves as a barrier against dirt and germs. A normal corneal exam will show a smooth clear surface of the eye. An abnormal corneal exam may show corneal abrasions, lacerations, foreign bodies, ulcers, rust ring, or cloudiness (as seen in glaucoma).

Anterior Chamber

The anterior chamber, located between the iris and cornea, is filled with fluid that provides oxygen and nutrients to the cornea and lens. To evaluate the anterior chamber most thoroughly, the clinician will use the slit lamp (**FIGURES 37.1** and **37.6**).

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Although there are no absolute contraindications to performing a slit lamp examination, patients with a globe injury should be examined carefully, so as to avoid placing any pressure on the globe.

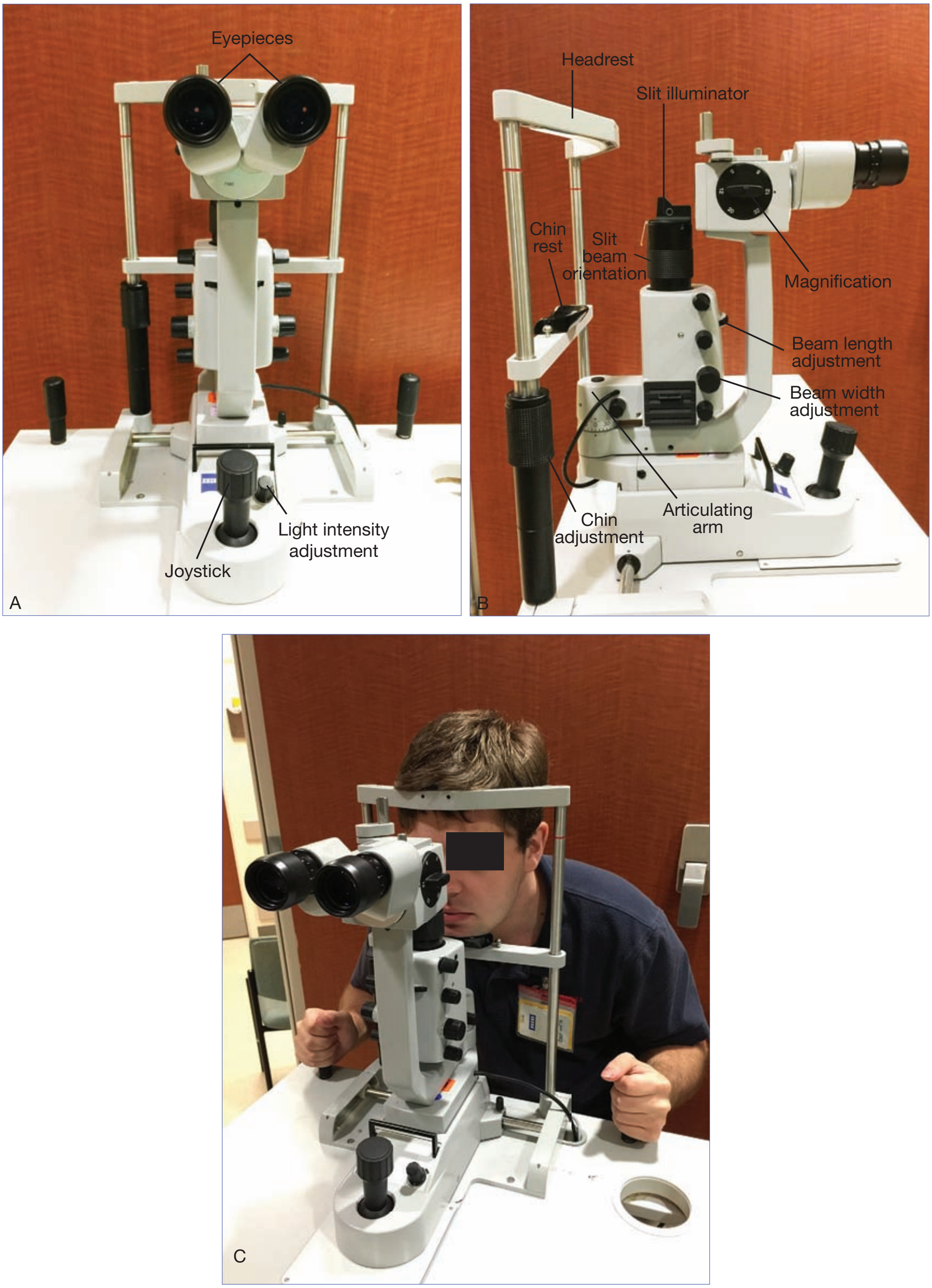
Eyepieces
Light intensity adjustment
Joystick
A
Headrest
Slit illuminator
Chin rest
Slit beam orientation
Magnification
Beam length adjustment
Beam width adjustment
Chin adjustment
Articulating arm
B
C

FIGURE 37.6 Slit lamp: (A, B) Two views and (C) proper positioning.

SLIT LAMP EXAMINATION

Patient Positioning

To position the patient correctly, have the patient sit on the edge of the bed or chair facing the examiner, with their chin in the chinrest and the head against the forehead strap. This position keeps the patient's eyes within the focal range of the slit lamp.

Using the Slit Lamp

Although there are different models of slit lamps available, the functionality and control of each model should be similar (**FIGURE 37.6**). The patient's eyes should be at the center of your eye field, and the pupils are aligned with a marker on the vertical bars of the slit lamp. This position can be achieved by elevating or lowering the chinrest using the levers that control the chinrest. When the patient is properly positioned, the room should be darkened to facilitate pupillary dilation. The slit lamp should be focused so there is a tall narrow vertical beam of white light that is directed at the eyelids at approximately a 45-degree angle. While looking through the ocular lenses, the examiner may make subtle adjustments with the joystick to maintain focus.

Viewing the Anterior Chamber

As indicated, the anterior chamber is an aqueous-filled segment of the eye between the cornea and the iris. To view the anterior chamber, the light source on the slit lamp should be directed toward the temporal side of the patient's head. The light source should project at a sharp angle across the cornea. Examine the anterior chamber for signs of debris and inflammation (cell and flare), indicating anterior uveitis or iritis. "Cells" are leukocytes and will appear as keratitic white spots floating within the anterior chamber, whereas "flare" is caused by increased aqueous protein and appears like "headlights in a fog" (Tintinalli, 2016, p. 1549). The anterior chamber should also be evaluated for hyphema (which is a layering of blood that is usually caused by trauma, and is usually visible to the naked eye) and hypopyon, which is a layering of white blood cells.

CORNEAL FOREIGN BODIES AND ABRASIONS

The superficial cornea should be examined for foreign bodies or abrasions. Corneal foreign bodies can often be seen without the use of fluorescein stain. Detection of corneal abrasions, however, usually requires fluorescein.

FLUORESCEIN STAINING

First, instill a few drops of anesthetic eye drops (proparacaine or tetracaine) and have the patient blink several times. Once the eye is anesthetized, place one or two drops of the anesthetic onto the fluorescein strip, and then touch the moistened strip to the anesthetized eye. Have the patient blink several times to distribute the eye stain. Once the patient is comfortably back in the slit lamp, change the light source to cobalt blue and focus on the superficial part of the cornea. Look for any uptake of the fluorescein stain. Uptake of stain in a linear distribution is indicative of a corneal abrasion, whereas ulcers are usually rounded and crater-like in appearance. Multiple, linear abrasions in a vertical pattern suggest a foreign body under the lid. Note any streaming of the fluorescein-stained aqueous humor (positive Seidel test) as this represents a full-thickness laceration to the cornea—refer immediately to ophthalmology.

FUNDOSCOPIC EXAMINATION

Although the slit lamp may be used to perform funduscopic examination, most ED clinicians tend to use a handheld ophthalmoscope. When performing the fundoscopic examination with a direct handheld ophthalmoscope, observe the size, shape, and sharpness of the optic disc; the cup-to-disc ratio; the ratio of arteries to veins; any nicking of vessels; the texture and color of the retina; as well as the presence of any lesions. Best viewing of the macula and vessels is accomplished with pharmacologic dilation, though this is not regularly done in the nonophthalmology setting. Darkening the room will assist with pupil dilation.

INTRAOCULAR PRESSURE MEASUREMENT

Intraocular pressure (IOP) can be measured with the slit lamp or a commercial digital tonometer. **Do not attempt to measure IOP if globe rupture is suspected.**

Normal IOP is 10 to 20 mmHg.

First, the Tono-Pen® should be calibrated according to the instructions (**FIGURE 37.7**). Next, the eye should be anesthetized, and then the tip of the Tono-Pen should be touched to the cornea lightly several times. An average measurement will appear on the liquid-crystal display (LCD).

The icare® device is another electronic device that can be used to measure IOP (**FIGURE 37.8**). To use the icare device, the examiner will turn on the device and follow the prompts to load a single-use measurement probe into the probe base. The forehead support will be placed on the patient's forehead; then, after aiming the probe in the center of the eye, the examiner places the probe 48 mm from the cornea. There should be a green light around the pro-base that indicates proper alignment. The examiner then presses and holds the measure button to perform the automatic measurement. There is no need to anesthetize the eye with this device.

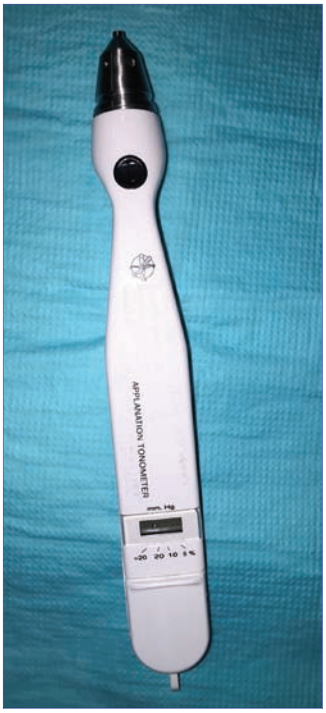

FIGURE 37.7 Tono-Pen.

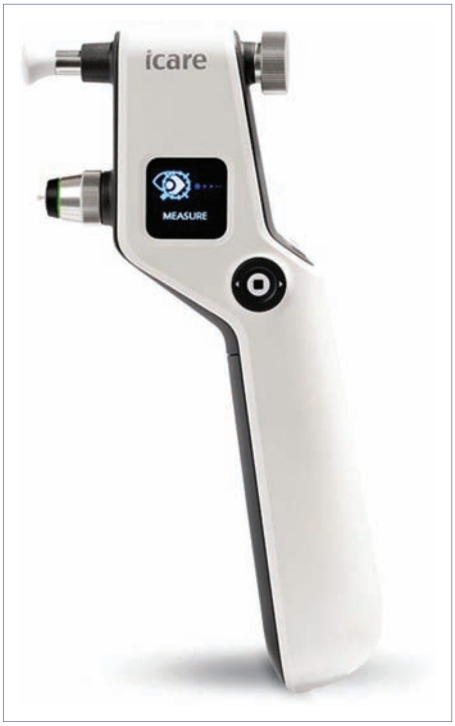

FIGURE 37.8 icare tonometer.

Source: Reproduced with permission from iCare-usa.com

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CHAPTER

38

Managing Eye Injuries

LaMon Norton

BACKGROUND

Although ocular trauma accounts for a small percentage of ED visits, its potential for life-changing consequences for the patient is high. Obtaining a detailed history during the initial assessment is crucial, as the history provides clues to the nature and scope of the injury as well as necessary information for documentation. If irrigation is emergently indicated, it should not be delayed to obtain the history. Priority components of the history include vision loss or sensations such as flashes or shadowing, changes in appearance of the eye (e.g., pupillary differences or irregularities), pain or discomfort, and any details of known trauma. Onset, duration, and circumstances surrounding the injury are also important. Tetanus immunization status should also be assessed and updated as needed. After the history is obtained, visual acuity should always be assessed before procedural intervention.

FOREIGN-BODY REMOVAL

PATIENT PRESENTATION

- Pain
- Blurry vision
- Tearing
- Foreign body
- Foreign-body sensation

TREATMENT

The suspected object and the location and depth of the object direct the type of removal. Foreign-body removal should be accomplished at the highest magnification possible. Superficial foreign-body removal may be achieved with simple normal saline irrigation, or with direct removal using a moistened cotton-tipped swab or 25- to 30-gauge needle. Penetrating foreign-bodies deeply embedded and beyond the cornea require an ophthalmology consultation.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Open globe, intraocular foreign body

SPECIAL CONSIDERATIONS

- Deep corneal foreign bodies may not be amenable to ED removal—referral to ophthalmology is preferred.
- A cooperative patient is necessary.

PROCEDURE PREPARATION

- Fluorescein stain
- Ophthalmic anesthetic
- Cotton-tipped swab
- 25- to 30-gauge needle with syringe
- Slit lamp preferable, if available, or magnification loupes
- Ophthalmoscope

PROCEDURE

- Instill two drops of anesthetic with fluorescein into the affected eye.
- Patient should be well stabilized or secured in the slit lamp frame.
- With the best magnification available, have patient fix their gaze.
- Attempts to dislodge foreign body should begin with the least invasive first, and escalate as needed. Begin with irrigation, then a moistened swab, then a syringe with a needle.
- Hold the swab or needle with the thumb and index fingers, resting the fifth digit and medial (ulnar) side of the clinician's hand on the patient's face (around the inferior orbital rim) for support (**FIGURE 38.1A**).
- While viewing through the slit lamp or magnification loupes, move the swab or syringe with the needle slowly toward the patient's eye, following the swab/syringe with the needle as it comes into focus.
- Once in focus, slowly and gently attempt to manipulate the device to dislodge the foreign body from the cornea.
- Do not dig deeply into the cornea.
- If the foreign body sticks superficially to the cornea, use the cotton swab and touch it to the foreign body and it will often stick to the swab (**FIGURE 38.1B**).

Rust-Ring Removal

Metallic foreign bodies will often result in the development of a "rust ring" subsequent to removal—this is a rust-colored stain of the cornea resulting from an oxidative response. The rust ring may be removed with a burr device or by manually scraping with a small-gauge needle on the syringe. Patients will need follow-up with an ophthalmologist for removal of the rust ring. Large rust rings may contribute to delayed corneal healing.

Cyanoacrylate Glue

These glues can cause a chemical keratitis upon corneal contact. They also may attach to the lid margins. Do not force the lids open if glued shut. Heavy application of petroleum-based products (erythromycin ointment, over-the-counter

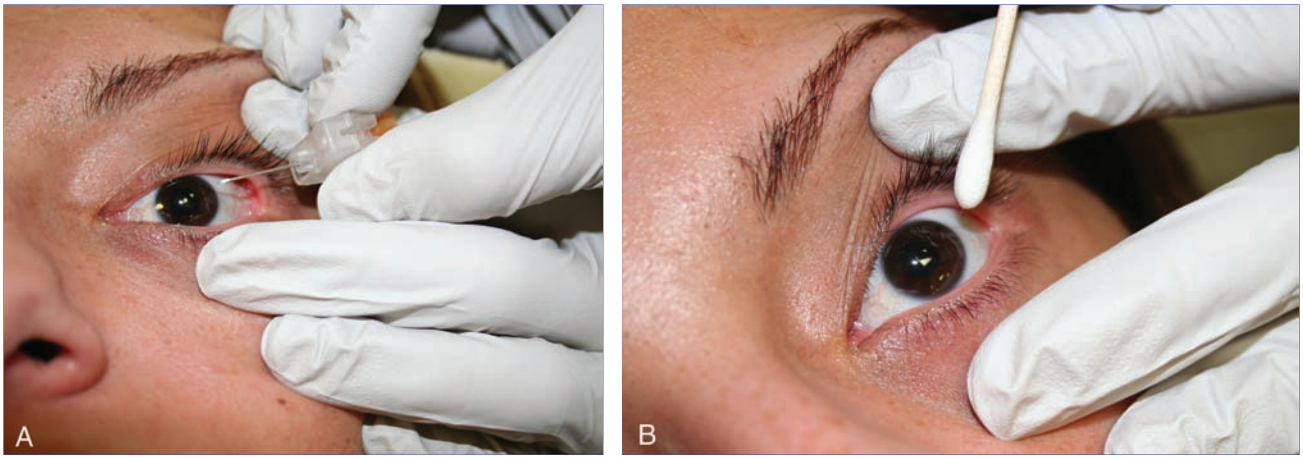

FIGURE 38.1 Foreign-body removal from the eye. (A) Using a small-gauge needle to remove foreign body. (B) Using a wet cotton swab. Note this is generally accomplished using a slit lamp and is pictured here without a slit lamp for clarity.

antibiotic ointment, or pure petroleum jelly) to the lids or on the cornea will degrade the glue in a short time. After removal of large pieces of debris, patient should be referred to ophthalmology and advised to continue erythromycin ointment application four to five times daily.

POSTPROCEDURE CONSIDERATIONS

- Rust rings should be addressed by an ophthalmologist.
- Cyanoacrylate glues on the cornea can leave a large, painful defect.
- Topical antibiotic may be prescribed, and should be strongly considered with injuries resulting from organic matter.

EDUCATIONAL POINTS

- Do not rub the eye.
- Advise the patient that irritation may return when the anesthesia wears off, but it should resolve on its own.
- Nonsteroidal anti-inflammatory medications can be taken for discomfort.
- Antibiotic ointment is often prescribed though supporting literature is scant.
- Do not use an eye patch.

COMPLICATIONS

- Corneal abrasion
- Infection

PEARLS

- Do not cause more damage when attempting to remove a corneal foreign body; if it is deeply embedded, an ophthalmologist may be required.
- Removal of a rust ring is not an emergency; ophthalmology follow-up is all that is required. If left in place, the rust ring will soften and may come out in one piece.
- Corneal abrasions present similarly to foreign bodies.
- High-speed metal (welding, grinding of metal) in the presentation of a foreign-body sensation demands ocular imaging (ultrasound and/or CT scan) in order to rule out an intraocular foreign body.
- Multiple linear corneal abrasions may result from an embedded foreign body adhered to the eyelids. The lids should always be everted fully and inspected.

CHEMICAL SUBSTANCE REMOVAL

BACKGROUND

Chemical exposures are ocular emergencies with high risk for permanent vision loss and/or perforation. The critical intervention for chemical substance exposure to the eye is prompt and copious irrigation. Even before completing an initial assessment or checking visual acuity, irrigation must begin. Use of either normal saline or lactated Ringer’s solution is appropriate. Exposure to alkaline substances is more common and may cause more penetrating damage due to liquefaction necrosis versus acid injuries, which cause a coagulation necrosis.

PATIENT PRESENTATION

- Pain
- Burning

- Tearing
- Photophobia
- Blurred or lost vision

TREATMENT

- Immediate irrigation with normal saline, lactated Ringer's solution, or tap water if saline is not readily available.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Open globe

SPECIAL CONSIDERATIONS

- Alkaline versus acidic substance

PROCEDURE PREPARATION

- Ophthalmic anesthetic
- Absorbent pads
- Large basin
- Normal saline or Ringer's lactate (liter bags of intravenous [IV] solution)
- IV tubing or commercial device (Morgan lens)
- pH paper (litmus)

PROCEDURE

IV Tubing

- Connect the isotonic solution to the IV tubing and run it through.
- Instill several drops of anesthetic.
- Place an absorbent pad under the patient's head.
- Place a large basin beneath the patient's head.
- Retract the eyelid.
- Irrigate for 30 minutes, then check pH; continue until pH is neutral.

Morgan Lens

- Connect the isotonic solution to the IV tubing and run it through.
- Instill several drops of anesthetic.
- Place an absorbent pad under the patient's head.
- Place a large basin beneath the patient's head.
- Retract the eyelid.
- Place the lens device under both the upper and lower lid directly onto the eye.
- Irrigate for 30 minutes, then check pH; continue until pH is neutral.

POSTPROCEDURE CONSIDERATIONS

- Check for corneal abrasions.
- Order ophthalmology referral for follow-up.

EDUCATIONAL POINTS

- Do not rub the eye.
- Advise the patient that irritation may return when the anesthetic wears off.
- Nonsteroidal anti-inflammatory medications can be taken for discomfort.

PEARLS

- You can connect the end of the intravenous tubing to the end of a nasal cannula if irrigation of both eyes is required.
- Irrigation may require large amounts of fluid to achieve physiologic pH.

CONTACT LENS REMOVAL

BACKGROUND

Contact lens wearers will present for help with removal at times. They may also present with symptoms of discomfort that are caused by lens wear. Lenses that are manufactured to be worn for long periods of time place the person at increased risk for *Pseudomonas* infection and corneal ulceration. Another common chief complaint is a missing or "lost" lens, which is not able to be found for home removal. A full examination should be completed to ensure that the lens is not caught in the fornices.

PATIENT PRESENTATION

- Foreign-body sensation
- Pain
- Redness
- Irritation

TREATMENT

- Removal of the contact lens is required.

PROCEDURE PREPARATION

- Ophthalmic anesthetic drops
- Fluorescein stain (will permanently discolor lens)
- Cotton-tipped swab
- Normal saline and IV tubing
- Commercially available suction cups

PROCEDURE

- Determine whether patient wears a hard or soft lens. If the wearer cannot find the lens, it is usually in the fornices. Everting the lid may help find it.
- While placing traction on the lid, have the patient look to all four quadrants and often you will find the lens stuck to the globe.
- Anesthetic drops are recommended.
- A wet cotton-tipped swab may also be used to move the lens.
- Once found, move it to the center of the cornea, where it can be removed.
- If the lens is adherent, irrigating with saline will often loosen it.
- Soft contacts, once found, can be gently squeezed between the thumb and forefinger (this will break the suction).

- Irrigation will not break the seal when removing a hard lens. Commercially available suction cups will adhere to the lens for removal.
- Always do a fluorescein examination after removal.

POSTPROCEDURE CONSIDERATIONS

Fluorescein Stain Uptake

- If there is uptake, remember to prescribe an antipseudomonal antibiotic drop.

EDUCATIONAL POINTS

- Do not wear contact lenses until symptom free.
- Follow up with an optometrist/ophthalmologist.

COMPLICATIONS

- Corneal abrasion

PEARLS

- Once you locate the lens, you can sometimes let the patient attempt removal.
- Fluorescein will permanently discolor the lens.

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CHAPTER

39

Ocular Ultrasound

Jordan Becker and Ryan C. Gibbons

BACKGROUND

Ambulatory and Hospital Care Statistics Branch (2017) reported that ocular diseases accounted for less than 1% of the emergency visits in the United States. **TABLE 39.1** outlines the most common acute visual conditions encountered, ***the majority of which can be diagnosed through simple visual inspection of the external eye.*** **TABLE 39.2** highlights the elements of a thorough ocular examination. Be sure to identify the signs of trauma or infection.

The use of adjuncts, such as a Wood's lamp, slit lamp, and Tono-Pen®, enable prompt and accurate diagnosis and treatment.

Numerous other disorders involve the posterior chamber of the eye. ***Traditionally, the use of ophthalmoscopy has augmented diagnostic evaluation. However, most primary providers lack sufficient training and skill, not to mention the capability to perform an appropriately dilated exam***.

Point-of-care ultrasound (POCUS) has become ubiquitous in nearly all fields of medicine. Its ease of use, portability, and accuracy make it an ideal diagnostic modality. In fact, ophthalmologists have been utilizing ocular US since the 1950s. **TABLE 39.1** highlights the many sonographic ocular diagnoses. Refer to **FIGURE 39.1A** for the normal sonographic appearance of the eye. Refer to **FIGURE 39.1B** for normal histologic layers of the posterior eye.

TABLE 39.1 Common Visual Conditions

Visual Conditions	Ultrasound Diagnosis
■ Periorbital cellulitis ■ Blepharitis ■ Hordeolum and chalazia ■ Conjunctivitis ■ Subconjunctival hemorrhage ■ External foreign body ■ Scleritis/episcleritis ■ Corneal abrasion or ulceration ■ Keratitis ■ Burn ■ Trauma ➢ Globe rupture ➢ Laceration ■ Cataract ■ Glaucoma ■ Anterior uveitis or iritis ■ Orbital cellulitis	■ Globe rupture ■ Cataract ■ Lens dislocation ■ Intraocular foreign body ■ Vitreous hemorrhage ■ Vitreous detachment ■ Retinal detachment ■ Retrobulbar hematoma ■ Embolic CRAO ■ Signs ➢ Papilledema ➢ ICP via ONSD

CRAO, central retinal artery occlusion; ICP, intracranial pressure; ONSD, optic nerve sheath diameter.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

TABLE 39.2 Ocular Examination

- Periorbital area
- Eyelids and lashes
- Globe
- Conjunctiva
- Sclera
- Iris
- Skin: Vesicular rash
- Temporal artery
- Facial bones and sinuses

- Visual acuity
- Intact EOM
- Pupil symmetry
- Direct and afferent pupillary response
- IOP
- Intact cranial nerves

EOM, extraocular movements; IOP, intraocular pressure.

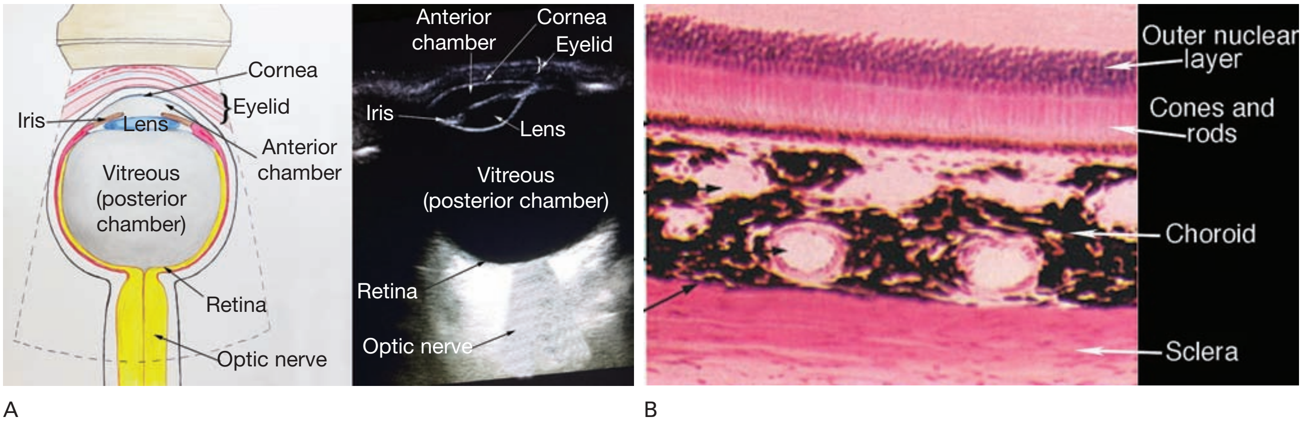

Cornea
Eyelid
Iris
Lens
Anterior chamber
Vitreous (posterior chamber)
Retina
Optic nerve
Anterior chamber
Cornea
Eyelid
Iris
Lens
Vitreous (posterior chamber)
Retina
Optic nerve
Outer nuclear layer
Cones and rods
Choroid
Sclera
A
B

FIGURE 39.1 (A) Normal eye anatomy sketch and ultrasound images side by side with similar labels. (B) Histologic layers of the posterior eye.

Ocular Anatomy

- Cornea
  - Most anterior image below the skin
- Anterior chamber
  - Fluid-filled area between the cornea and the lens
  - Anechoic
- Iris
  - Rounded membrane behind the cornea and anterior to the lens
- Lens
  - Posterior to the iris
  - Hyperechoic image
    - Posterior reflection waves seen
- Posterior chamber
  - Fluid-filled area posterior to the lens
  - Anechoic
- Vitreous body
  - Filled with vitreous gel
    - Encased on a vitreous membrane
  - Allows the eye to maintain its spherical structure
- Sclera
  - Outermost portion of the eye
- Choroid
  - Medial to the sclera and lateral to the retina
  - The choroid is the vascular layer and provides oxygen and nourishment to the outer layers of the retina
  - In globe ruptures, the black vascular choroid layer can often be seen penetrating through the sclera upon close physical examination

- Retina
  - Innermost portion of the eye
  - In the normal eye, the retina, choroid, and sclera are seen sonographically as one layer
  - Arises from a splaying of the posteriorly derived optic nerve and composed of photoreceptors
    - Responsible for vision
    - Oxygen dependent on the adjacent lateral (medial to the sclera) choroid layer
- Macula
  - Lateral to the optic nerve
  - Indentation of the retina
  - Highest concentration of photoreceptors
  - Responsible for central vision
- Fovea
  - Most central part of the macula
  - Highest number of photoreceptors in the macula
- Optic nerve
  - Posterior to the retina
  - Hypoechoic
  - By the use of US measurement one can obtain a high sensitivity for detecting elevated intracranial pressure (ICP; see text that follows as well as Chapter 70, Procedures for Performing Lumbar Puncture).

VISUAL LOSS OR DISTURBANCES

POSTERIOR VITREOUS DETACHMENT AND VITREOUS HEMORRHAGE

PATIENT PRESENTATION

- Signs and symptoms
  - Vitreous hemorrhage (VH)
    - Painless “floaters”
      - May be prominent.
    - Reddish tint to the vision
    - Blurry vision
  - Posterior vitreous detachment (PVD)
    - Photopsia (“flashes”)
      - Unlike retinal detachment, this occurs in only 50% of patients.
- Risk factors
  - Posterior vitreous detachment
    - Age >60 years
    - Myopia
    - After cataract surgery
    - Facial trauma
  - Vitreous hemorrhage
    - Diabetes
      - ***Diabetic retinopathy is the leading cause of VH in adults, as fragile blood vessels spontaneously hemorrhage.***
    - Trauma
      - Leading cause of hemorrhage in the young
    - Retinal detachment
    - Posterior vitreous detachment
    - Sickle cell retinopathy
    - Macular degeneration
    - Central vein occlusion

Pathophysiology

Posterior vitreous detachment is a common disorder found in 23% of autopsy cases, increasing throughout the life span to more than 50% in those older than 80 years. Many detachments are asymptomatic and usually occur spontaneously but may occur secondary to trauma or irritation secondary to recent ocular surgery or disease. Aging induces degeneration and breakdown of the vitreous gel, causing it to liquefy in some areas and shrink in others. The fluid collects in pockets/cavities, and thick strands of the gel form and drift through the eye and appear as floaters. When these changes occur suddenly, the vitreous membrane separates from the retina and a PVD arises. This is usually of little sequelae and the floaters resolve over time; the biggest fear is the formation of a traction-induced rhegmatogenous retinal tear.

- In summation, the vitreous detachment occurs when the vitreous gel that fills the eye involutes or degenerates to pull the vitreous membrane off of the retina and the sequela of traction at the attachment site of the vitreous membrane to the retina causes bleeding into the vitreous.
  - In other words, PVD may cause a VH.

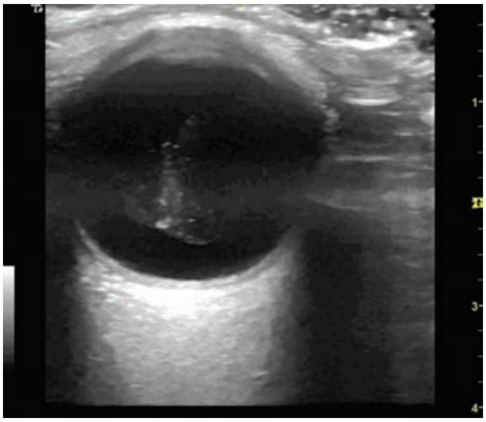
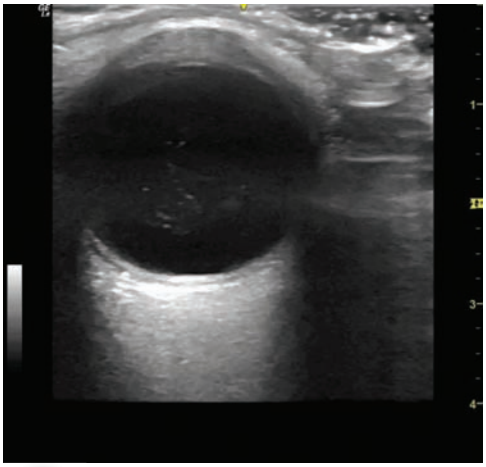


FIGURE 39.2 Vitreous hemorrhage. Note the "washing machine" or "snow globe" effect.



VIDEO 39.1 Vitreous hemorrhage. Note washing machine effect of the vitreous blood with eye movement.

Sonographic Findings

- Swirling heterogeneous, hyperechoic material in the vitreous humor (**FIGURE 39.2** and **VIDEO 39.1**)
  - Blood in VH can be solid, liquefied, or both; solid blood is often found in the middle of the posterior chamber, whereas liquefied blood will layer more posteriorly.
    - Can also be seen as hyperechoic "snowflakes" or "speckles"
- Thin, faint hyperechoic serpiginous artifact (**FIGURE 39.3** and **VIDEO 39.2**)
- If visualization of PVD and VH is difficult, increasing the gain may be helpful.

PVDs look similar to a retinal detachment, except the former is:

- Only attached to the choroid in one place
- Thinner and more difficult to see without the US gain set very high
- Associated with "after-movements"—having the patient move their eye creates undulations of the structure that continue after the eye has stopped moving
- Less hyperechoic, more mobile, and not tethered to the optic nerve

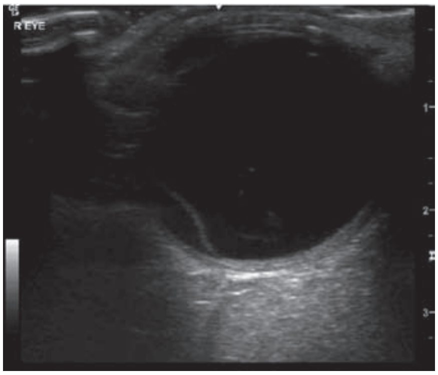
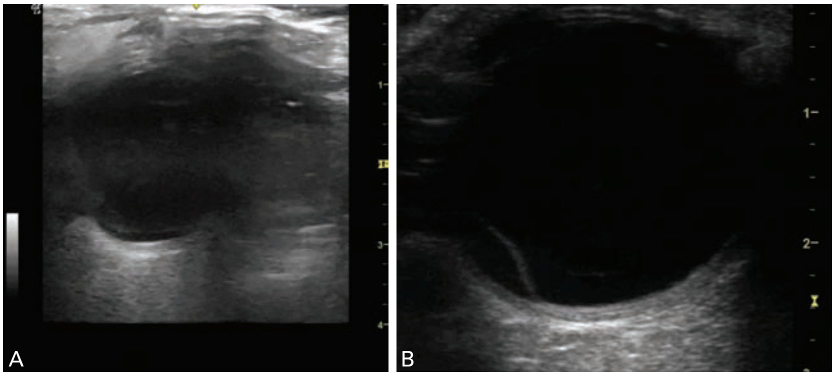


FIGURE 39.3 Posterior vitreous detachment.



VIDEO 39.2 Increasing the gain assists with visualization of the PVD and VH (A). Note the thin, faint hyperechoic serpiginous artifact (B).

RETINAL TEAR, DETACHMENT, AND HEMORRHAGE

PATIENT PRESENTATION

- Signs and symptoms
  - Photopsia
    - Not pathognomonic as can be seen in:
      - PVD
      - Migraine aura
      - Occipital lobe cerebrovascular accident (CVA)
  - Blurry vision
  - Floaters representing vitreous blood
    - Note that floaters are not pathognomonic for blood as they can also be from aging vitreous gel strand formation
  - Shadows, curtain
  - Variable degrees of loss of vision depending upon the size
    - Visual field defects localize the detachment site
- Risk factors
  - Age ≥40 years
  - History of the same
  - Myopia
  - Vasculitis
  - Family history
  - Recent ocular surgery
  - Trauma

Pathophysiology

The retina is normally tightly bound and “tacked down” to the posterior/lateral wall of the eye and is attached in two places: posteriorly at its origin, the *optic nerve*, and anterior laterally, at the *ora serrata* (serrated junction between the retina and the ciliary body where the anterior lateral nonphotosensitive area of the retina is tethered down). All retinal detachments are easily sonographically visualized somewhere between these two anchored areas of fixation. This photosensitive tissue has no pain fibers, and therefore this condition is painless. Retinal detachment is any separation of the retina from the choroid and occurs at a rate of one in 300 over a lifetime. It appears to be free-floating, but will not continue to undulate or tumble when the patient stops moving the eye (in contrast to posterior vitreous detachment). Acute retinal detachments are attached in two places, whereas chronic detachments may be attached in one location. Next to central retinal artery occlusion, chemical burns to the eye, and endophthalmitis, it is one of the most time-critical eye emergencies encountered in the emergency setting.

Treatment in all cases generally involves “tacking down” the retina in order to halt its *ongoing detachment progression*. In smaller tears, this usually is accomplished via laser photocoagulation or cryopexy. Larger and “mac on” (macula not involved) tears are treated more aggressively in order to preserve this vital area. With prompt diagnosis, 90% of tears can be successfully treated, although sometimes a second treatment is needed. There are three types of detachments:

- Rhegmatogenous detachment
  - Most common type
  - Results when a tear/break in the neuronal inner retinal layer allows fluid from the vitreous to seep between the retina and the choroid
- Traction detachment
  - Results from adhesions between the vitreous gel and the retina
- Exudative detachment
  - Results from exudation of material into the subretinal space from retinal vessels
    - Hypertension
    - Central retinal venous occlusion
    - Vasculitis
    - Papilledema

Sonographic Findings

- Serpiginous movement of an echogenic piece of tissue in the posterior portion of the eye (**TABLE 39.3**, **FIGURE 39.4**, and **VIDEO 39.3**).
- Retinal tether points to the optic disc and ciliary bodies appear as a V-shape (**FIGURE 39.5**).

TABLE 39.3 **Retinal Versus Posterior Vitreous Detachment**

	RD	PVD
Mobility	Less; typically only with EOM	More; freely mobile
Echogenicity	More	Less (increase gain)
Thickness	More	Less
Optic nerve	Does not cross, tethered	Can cross, not tethered
Vision loss	Yes	Rare; often occurs with VH.
Ocular emergency	Yes	No; requires routine follow-up.

EOM, extraocular movement; PVD, posterior vitreous detachment; RD, retinal detachment; VH, vitreous hemorrhage.

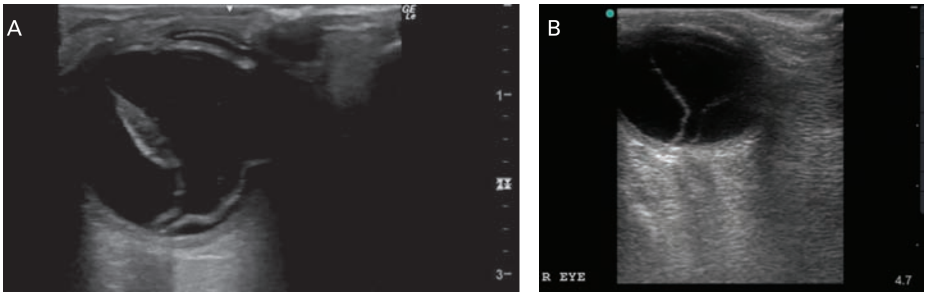
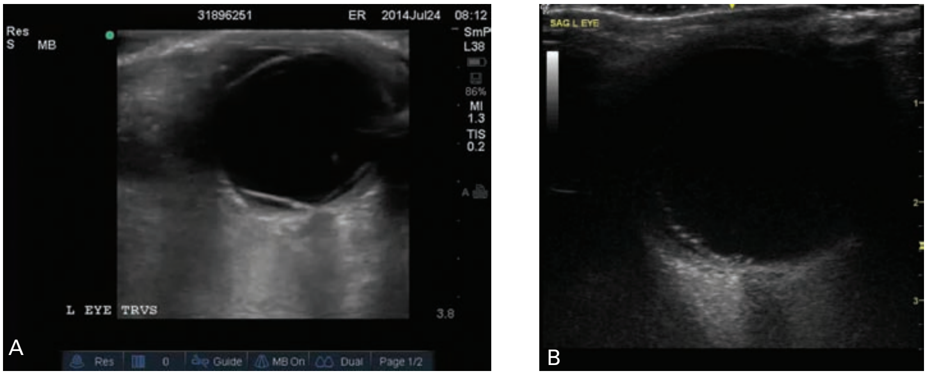

A
1
3
B
R EYE
4.7

FIGURE 39.4 Retinal detachment tethered to the optic nerve.


31896251
ER 2014Jul24 08:12
Res
S
MB
SmP
L38
MI
1.3
TIS
0.2
L EYE TRVS
3.8
A
SAG L EYE
1
2
3
B

VIDEO 39.3 Retinal detachments tethered to the optic nerve. Note the differences between retinal detachment and vitreous detachments.

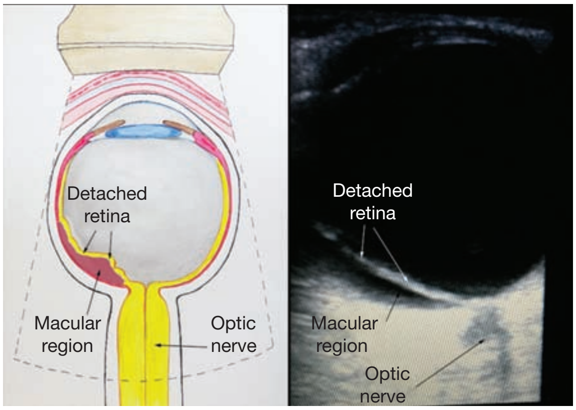

Detached retina
Macular region
Optic nerve
Detached retina
Macular region
Optic nerve

FIGURE 39.5 Retinal detachment. Note the retina detaches from the choroid layer.

CENTRAL RETINAL ARTERY OCCLUSION

PATIENT PRESENTATION

- Signs and symptoms
  - Acute onset of monocular, painless vision loss
- Risk factors
  - Hypertension
  - Hyperlipidemia
  - Diabetes mellitus
  - Cerebrovascular and cardiovascular disease
  - Hypercoagulable conditions
  - Atrial fibrillation
  - Rheumatologic disease
  - Smoking

Pathophysiology

- Embolic cause (19%–31%)
  - *CVA equivalent
- Nonembolic cause: Thrombosis, vasculitis, dissection

Sonographic Findings

- Punctate hyperechoic embolus in the retrobulbar space within the optic nerve sheath. Note the central retinal artery courses the optic nerve and splays out to supply blood to the retina. The central retinal artery is a branch off of the ophthalmic artery, which in turn is a branch of the internal carotid artery. Alongside the central retinal artery is the central retinal vein. Also, running laterally in the optic nerve sheath are the bilateral posterior ciliary arteries that supply the head of the optic nerve.
- Color Doppler demonstrates absent or decreased blood flow through the central retinal or posterior ciliary arteries (**FIGURES 39.6** and **39.7**).

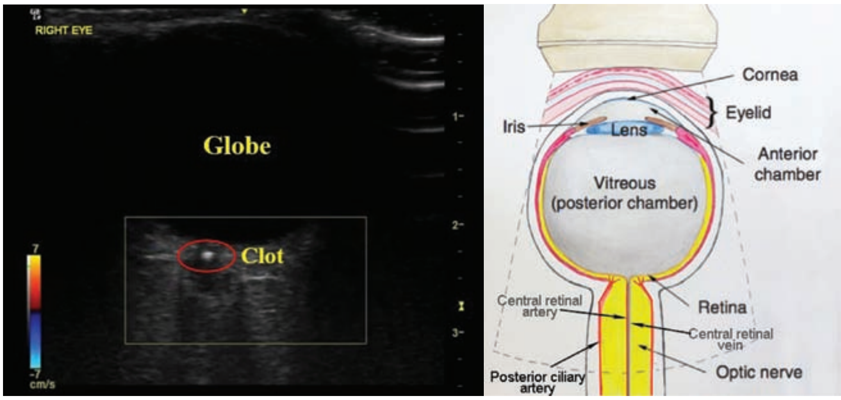

RIGHT EYE
Globe
Clot
7
-7
cm/s
1
2
3
Cornea
Eyelid
Iris
Lens
Anterior chamber
Vitreous (posterior chamber)
Central retinal artery
Retina
Central retinal vein
Posterior ciliary artery
Optic nerve

FIGURE 39.6 Hyperechoic embolus without blood flow.

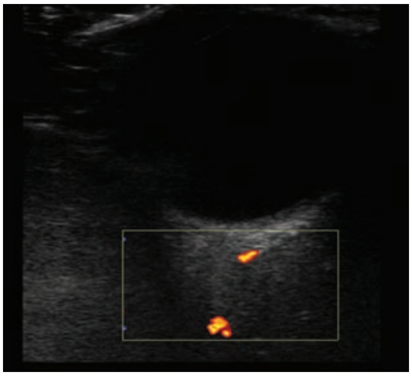


FIGURE 39.7 Normal ocular blood flow with the absence of a hyperechoic embolus.

INCREASED ICP

PATIENT PRESENTATION

- Altered mental status
- Focal neurologic deficit
- Headache
- Vision loss
- Traumatic injury

Pathophysiology

- Optic nerve sheath diameter (ONSD)
    - Contiguous with subarachnoid space; therefore, ICP changes transmitted to it
- A prospective study done in the ICU with ICP monitoring showed a strong correlation between the ONSD (over 5 mm) and the ICP (>20 cm H_2O); authors concluded that the ONSD measured through ocular ultrasonography is a useful method, because it is noninvasive and dynamic in patients with idiopathic intracranial hypertension (IIH), which allows reducing the inherent complications related to invasive methods.
- Advantages include the following:
    - It's a direct ***quantitative*** measurement, not a ***qualitative*** one like papilledema.
        - The optic nerve sheath is distensible and communicates with the subarachnoid space of the entire central nervous system (CNS) so you are detecting ICP pressure changes transmitted to the subarachnoid space via the resulting ONSD; this is a much more direct measure of ICP.
    - ***Papilledema takes time to develop as it requires ICP to increase, fluid pressure in the optic nerve sheath to constrict the optic nerve, and axonal transport to back up enough to cause swelling at the optic disc; this can take hours to weeks to manifest. And in an emergent situation an acutely ill patient may not have sufficient time to develop papilledema, but still have significantly elevated ICP.***
    - Papilledema can persist for 6 to 10 weeks following resolution of elevated ICP and it is not a great tool for monitoring ICP once papilledema occurs as if it worsens, you cannot distinguish if it is from worsening ICP or just the natural progression of the papilledema.
    - Accessibility
    - Cost
    - Monitoring/repeat exams
    - Noninvasive
    - Measurements: The average of three separate measurements of each eye taken 3 mm back from the globe in the anterior retrobulbar compartment
        - <5 mm normal (**FIGURE 39.8**)
        - 5 to 6 mm indeterminate, clinically correlate
        - *>6 mm abnormal*
        - *The problem is that a lot of patients fall into the ~5- to 6-mm gray zone; additional features, such as optic disc elevation (see text that follows), help to further differentiate these patients.*
        - *The further increase in size from 6 mm, the more the specificity increases* (**FIGURE 39.9**).

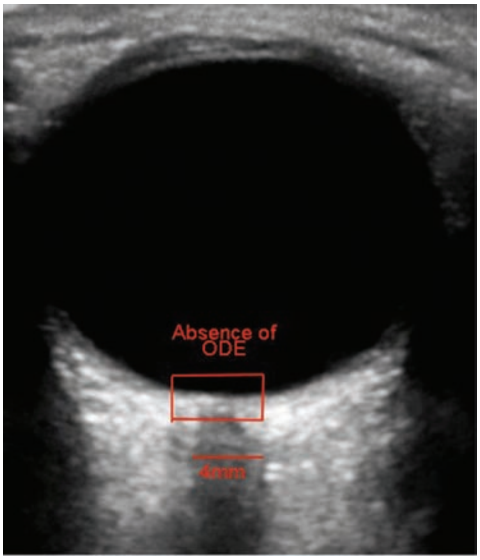


FIGURE 39.8 Normal ocular ultrasound. Note the normal optic nerve sheath diameter (ONSD; <5 mm) and the absence of optic disc elevation.

ODE, optic disc elevation; ONSD, optic nerve sheath diameter.

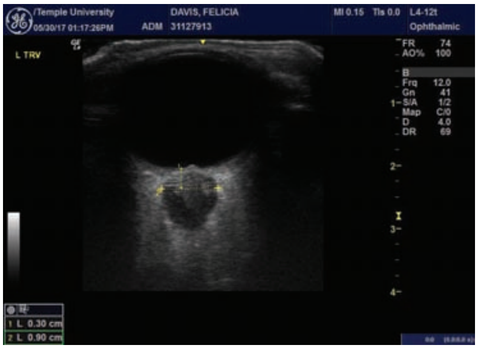


FIGURE 39.9 Enlarged ONSD of 9 mm measured 3 mm posterior to retinal surface.

ONSD, optic nerve sheath diameter.

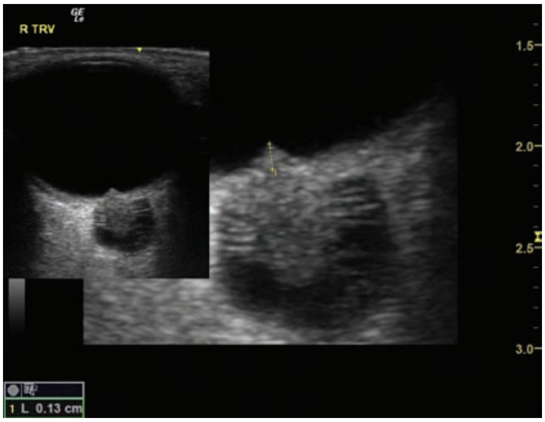


FIGURE 39.10 ODE of 13 mm *from the retinal surface.*

ODE, optic disc elevation.

  - US measurements accurate to within 0.5 mm of CT measurements
    - Correlation coefficient *r* for CT versus US = 0.8413
    - Single center, *n*, inexperienced operators
  - Limitations
    - Mostly single-center studies with small study populations
    - Specific patient populations: IIH (previously known as *pseudotumor cerebri*), traumatic brain injury (TBI), intracranial hemorrhage, malignancy
    - Typically with invasive ICP monitoring, that is, lumbar puncture (LP) or ventriculostomy; some compared ONSD to CT findings only
    - Significant heterogeneity within studies
    - Poor inter-rater reliability
    - Variable limits defining elevated ICP (20–30 cm H_2O or 20 mmHg)
    - Variability with measurements from 5–6 mm
    - Operator dependent
- *Optic disc elevation* (**FIGURE 39.10**)
  - ***Delayed finding in acute ICP elevation (as opposed to ONSD) and represents papilledema; takes time to develop after an acute rise in ICP elevation***

A small single-center study in a neuro-ophthalmology clinic of 14 patients with conditions associated with ODE—IIH (*n* = 8), multiple sclerosis (*n* = 5), and neuromyelitis optica (*n* = 1)—resulted in ODE of 0.6 mm to 82% sensitivity, 1.0 mm to 100% specificity, and a correlation coefficient *r* for CT versus US = 0.836. Again, this is more likely in chronic conditions.

Lochner et al. (2016) performed a prospective multicenter study comparing 21 patients with known intracranial hypertension versus age-matched controls. Ultrasonographic papilledema was present bilaterally in 20/21 (95%) of patients with intracranial hypertension, but was absent bilaterally in all 21 control patients. Papilledema outperformed ONSD (which had 93% sensitivity and 67% specificity, using a cutoff of 5.9 mm).

Carter et al. (2014) found ultrasonography to be 90% sensitive for papilledema in a retrospective chart-review series of 87 patients.

Teismann, Lenaghan, Nolan, Stein, and Green (2013) found that optic disc height on ultrasonography correlated well with optical coherence tomography among 14 patients evaluated in an ophthalmology clinic (*r* = 0.84; **FIGURE 39.10**). One strength of this study is that sonography was performed by emergency physicians, rather than US technicians.

Bäuerle and Nedelmann (2011) formed a prospective study involving 10 patients diagnosed with IIH and 25 patients with neurologic disorders not associated with intracranial hypertension. Ultrasonographic papilledema was present bilaterally in nine/10 patients and absent in 25/25 control patients. Papilledema outperformed ONSD (which had 90% sensitivity but only 84% specificity using a cutoff value of 5.8 mm).

In true papilledema, ICP is transmitted along the subarachnoid space within the optic nerve. The optic nerve is slightly widened, and an echolucent circle within the optic nerve sheath (separating the sheath from the optic nerve) is sonographically known as the *crescent sign* (**FIGURE 39.11**).

In a study using MRI as the gold standard for diagnosing 50 patients having papilledema, 46 (92%) showed crescent sign on B scan ultrasonography. Headache was the most common presenting complaint in 47 (94%) patients and IIH was the most common underlying cause of papilledema in 30 (60%) cases. ONSD combined with ODE may be another modality in evaluating ICP elevation although more standard methods still need to be employed until more randomized controlled trials (RCTs) are carried out.

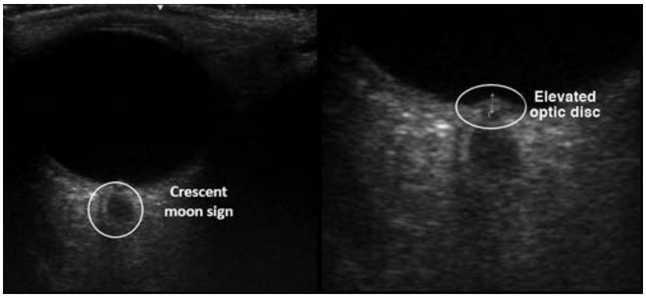


FIGURE 39.11 ODE with crescent-moon sign.

ODE, optic disc elevation.

CONCLUSIONS

"Crescent sign" seen on ultrasonography is a sensitive tool for the diagnosis of papilledema. It is a cost-effective, less cumbersome, and effective tool to differentiate between papilledema and pseudo-papilledema before subjecting the patients to costly investigations like MRI. A positive crescent sign should always be followed by MRI to find out the cause of papilledema.

TRAUMATIC OCULAR CONDITIONS

LENS SUBLUXATION AND DISLOCATION

PATIENT PRESENTATION

- Signs and symptoms
  - Blurry vision
  - Loss of vision
  - Monocular diplopia
- Risk factors
  - Trauma
  - Vasculitis
  - Myopia
  - Connective tissue disorder

Pathophysiology

- Zonular fibers connect the lens to the ciliary body. ***Most common secondary to cases of blunt trauma.*** Hereditary presentations are usually bilateral and associated with other disorders such as Marfan syndrome. The lens can migrate either to the anterior chamber or become free-floating in the posterior vitreous or become subluxed and remain partially within the lens fossa. Vision is blurred if the lens is dislocated out of the line of vision; however, if the dislocation is partial the visual prognosis is favorable. Iritis and glaucoma (pupillary block) are common complications. Nonsurgical corrective lenses usually are the treatment needed to accommodate for the refractive error. Indications for surgery include the following:
  - Anterior chamber dislocation
  - Uveitis
  - Glaucoma
  - Lens opacification with poor visual function
  - Refractive error not amenable to optical correction

Sonographic Findings

- Findings vary depending on type of dislocation
  - A partial dislocation: Tethered to the normal anatomic location of the lens (**FIGURE 39.12A**)
  - A complete lens dislocation: Hyperechoic lens in the vitreous chamber (**FIGURE 39.12B**)

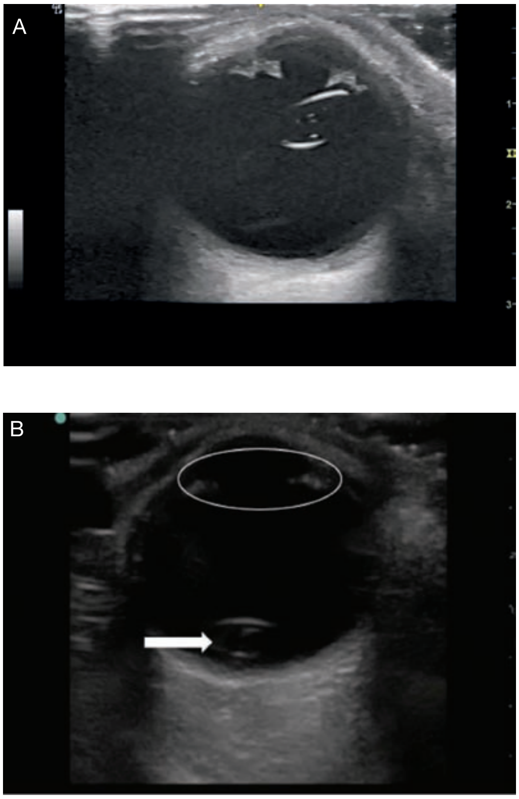


FIGURE 39.12 (A) Partial lens dislocation. (B) Posterior complete lens dislocation.

INTRAOCULAR FOREIGN BODY

PATIENT PRESENTATION

- Penetrating injury
  - Average age 38 years and usually male
  - Most common cause of ocular injury is hammering
  - Most intraocular foreign bodies (FBs) are metallic
  - Factors associated with poor visual outcome are the following:
    - Age >50 years
    - Decrease in initial visual acuity
    - Retinal breaks
    - Endophthalmitis

Physical Examination

Penetrating injury has a low sensitivity for detection so a high clinical suspicion must prevail; this type of injury warrants further imaging. May see black choroid layer through a subtle sclera penetration (**FIGURE 39.13**).

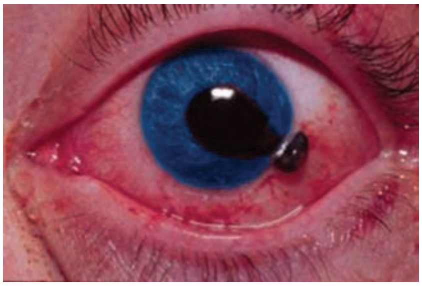


FIGURE 39.13 Penetrating missile injury to the eye. Note irregularly shaped pupil and extrusion of black choroid as well as an intraocular foreign body.

Pathophysiology

Intrusion of FB into globe

Sonographic Findings

- Hyperechoic foci with possible posterior shadowing or reverberations depend on the composition of the FB (see **FIGURE 39.14**)
- CT has highest sensitivity
- Wood/organic FBs are detected <50% of cases in all imaging modalities
- Shokri et al. (2017) compared the sensitivities (specificities were all 100%) of three different imaging modalities in the diagnosis of intraocular FBs. Findings are listed in **TABLE 39.4**.
- Endophthalmitis is a dreaded complication in 3% to 30% of cases involving intraocular FBs; therefore, patients with this injury should be given immediate treatment with prophylactic antibiotics.
- Systemic administration of fluoroquinolones is a good option because of their superior intraocular penetration.
  - The association is reduced to 0.9% with 48 hours of intravenous antibiotics and prompt ophthalmology intervention.
- Look for sign of globe rupture (see **FIGURE 39.13**)

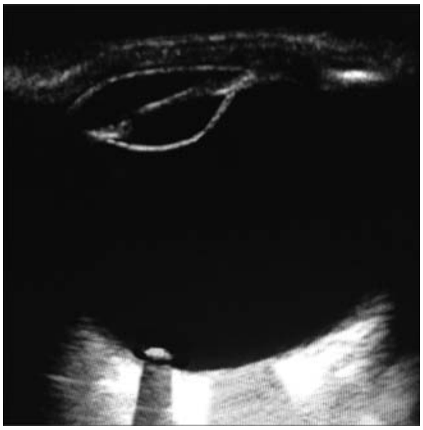


FIGURE 39.14 Intraocular foreign body. Note posterior shadowing.

TABLE 39.4 Sensitivities for CT, Ultrasound, and MRI for Detecting All Types of Intraocular Foreign Bodies

Imaging Modality	Sensitivity
*CT	79%
Ultrasound	33%
MRI	21%

*Note that this study was for all types of foreign bodies (FBs). Dass, Ferrone, Chu, Esposito, and Gray (2001) have shown that CT of the orbits without contrast (3 mm cuts) carries a 100% sensitivity in detecting 0.5-mm diameter metal, glass, and pebble FBs and is the modality of choice in suspected cases.

GLOBE RUPTURE

PATIENT PRESENTATION

- Signs and symptoms
  - Irregularly shaped pupil
    - Eccentric/teardrop pupil (**FIGURE 39.15**)
  - Diminished visual acuity
    - Afferent pupillary defect (APD)
  - Hyphema
  - Decreased extraocular mobility
  - Periorbital swelling often prevents the patient from opening the eye; may need to use curved paper clips (**FIGURE 39.16**)
  - Loss of normal circular shape
  - Decrease in the size of the globe
  - Anterior chamber collapse
  - Extrusion of vitreous
  - Projecting FB from eye
  - Positive Seidel test
    - Performed by applying fluorescein and observing for dye streaming away from the puncture site by leaking aqueous humor, indicative of penetrating trauma; however, it is important to recognize that the Seidel sign has sensitivity of just 70%.

Pathophysiology

Any complete violation to the cornea or sclera is defined as an *open globe injury*. This is an ophthalmologic emergency and mandates an immediate ophthalmology consultation. Globe rupture may occur when a blunt object impacts the orbit, compressing the globe, and inducing a sudden and transient elevation in intraocular pressure (IOP), resulting in a scleral tear. Ruptures from blunt trauma are most common at the sites where the sclera is thinnest, at the insertions of the extraocular muscles, limbus, and at the site of previous intraocular surgery. Sharp or small missile bodies traveling at high velocity may directly pierce the globe. The possibility of globe rupture should be considered and ruled out during the evaluation of all blunt and penetrating orbital/facial traumas as well as in all cases involving high-speed projectiles with potential for ocular penetration. One third of all cases of childhood blindness are secondary to ocular trauma.

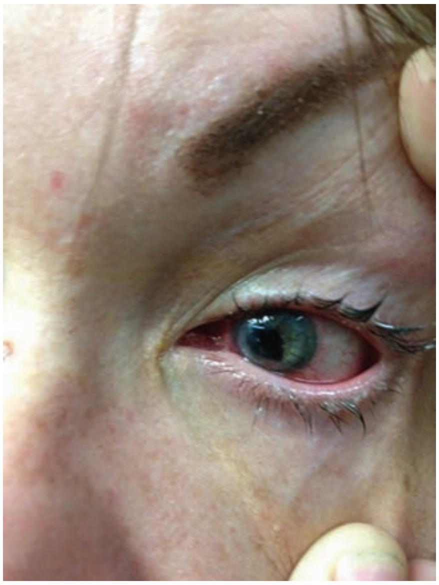


FIGURE 39.15 Irregularly shaped pupil.

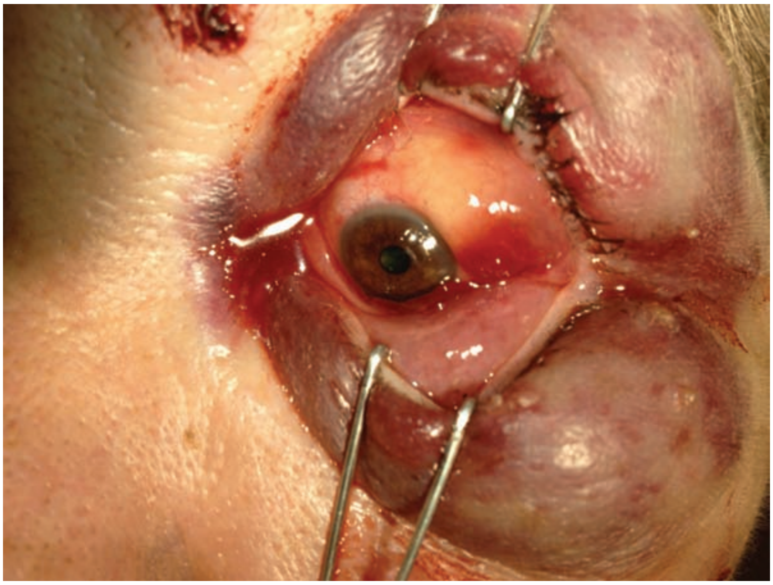


FIGURE 39.16 Paper-clip method of eyelid retraction.

Sonographic Findings

- Apply copious gel to minimize pressure (**FIGURE 39.17, VIDEO 39.4**)
  - Do not press the probe directly upon the eye.
- Misshapen globe with smaller than normal volume
- VH or lens dislocation may be present
- Loss of the normal demarcation between the anterior and posterior chambers; overall ambiguous anatomy
  - Echogenicity of the normal anechoic posterior chamber
- Chandra et al. (2009): 79% sensitivity for any abnormality, 61% sensitivity for rupture
  - Improves with experience
  - Limitations: Single-center, porcine models
- CT has higher sensitivity (**FIGURE 39.18**).

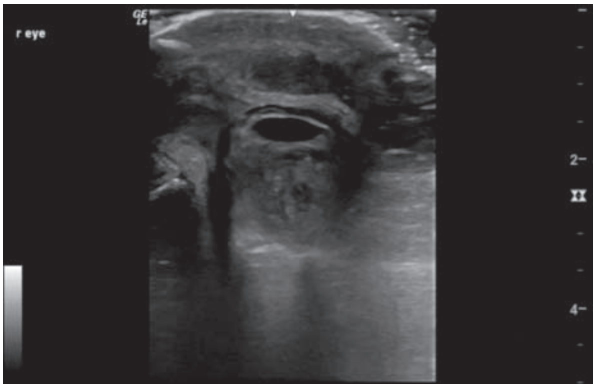
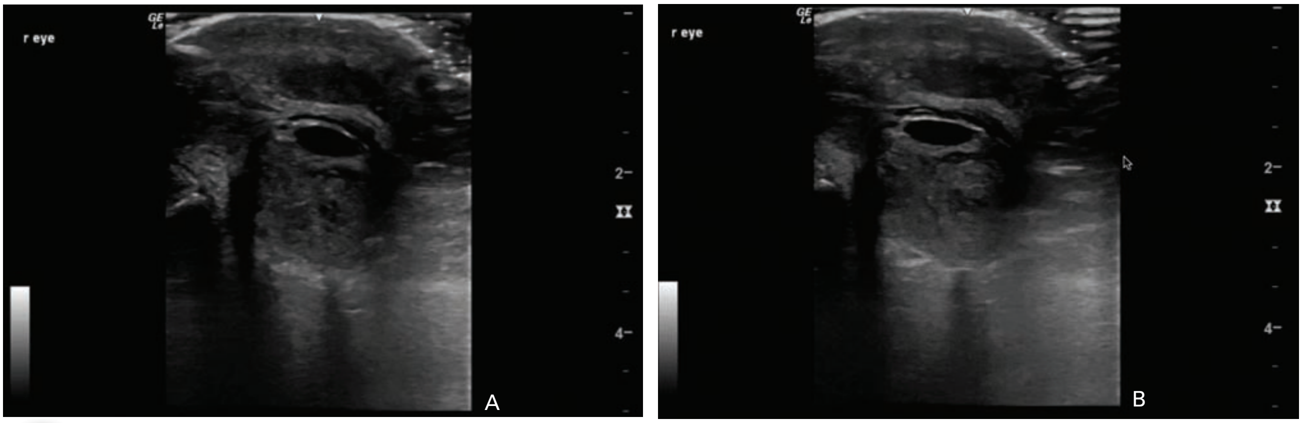


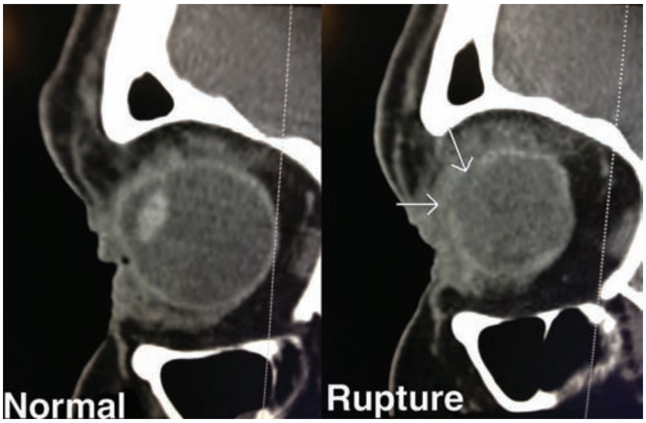
FIGURE 39.17 US of globe rupture with irregularly shaped pupil and globe. Note the overall ambiguous anatomy and loss of the normally anechoic posterior chamber.

US, ultrasound.



VIDEO 39.4 Globe rupture.

FIGURE 39.18 CT of globe rupture. Note the regular round appearance of the normal globe and the irregular appearance/indentation of the ruptured globe.



RETROBULBAR HEMATOMA (RETRO-ORBITAL HEMATOMA)

PATIENT PRESENTATION

- Severe pain, proptosis, vision loss, and an afferent pupillary defect
- Potential for increased IOP
  - *Measure prior to US*

Pathophysiology

- Bleeding into retrobulbar space creates:
  - *Transmission of pressure to ocular chamber*
    - Prompt diagnosis is critical, as ocular compartment syndrome can result from extension of the hematoma.
      - Intraocular ischemia secondary to increased IOP
      - Raised intraorbital pressures lasting for just 60 to 100 minutes can lead to permanent visual sequelae.
      - Definitive therapy is a medial canthotomy and should not be delayed for ophthalmology consultation considering this is a true compartment syndrome and visual loss is permanent.

US Findings

- Hypoechoic material will be seen in the retrobulbar space (**FIGURE 39.19** and **VIDEO 39.5**).
- Gibbons, Zanaboni, Patterson, and Costantino (2018): Sensitivity 85%, negative predictive value (NPV) 95.9%; >10 ocular scans 95% sensitivity
  - Limitations: Cadaver study, single center

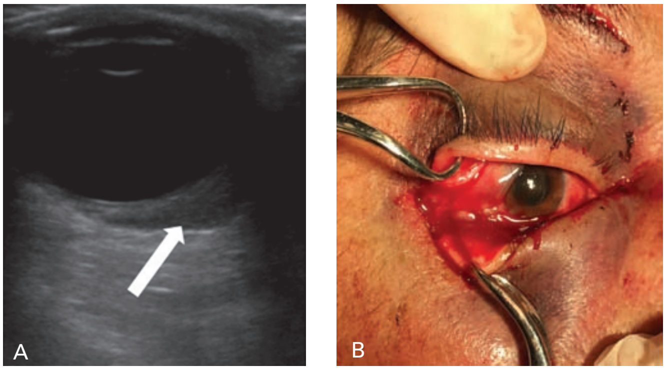
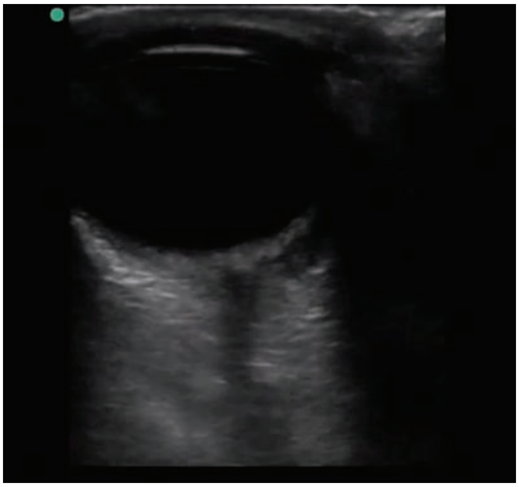


FIGURE 39.19 (A) Retrobulbar hematoma US showing a small hypoechoic area posterior to the retina. (B) Patient with a retrobulbar hematoma undergoing an emergent bedside lateral canthotomy. Note this is a compartment syndrome of the eye and must be treated immediately; otherwise, permanent vision loss will ensue.

US, ultrasound.



VIDEO 39.5 Retrobulbar hematoma.

TREATMENT

- Point-of-care ocular ultrasound (POCUS) is a diagnostic imaging modality.
- Presently, there are no bedside applications for the treatment of ocular conditions.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

There are no contraindications. Globe rupture is a relative contraindication.

PROCEDURE PREPARATION

- Apply a sterile probe cover to the linear, high-frequency (vascular) probe.
- Stand to the right of the patient facing cranially. Place the patient in the supine position. Dim the lights and raise the bed to an appropriate height.
- Have the patient gently close the eye.
- Adhesive eyelid cover (optional):
  - To limit potential ocular irritation from the gel
  - If utilized, minimize air pockets underneath the adhesive cover, particularly along the nasal border (**FIGURE 39.20**).
- Apply ***copious*** sterile gel to enhance imaging and to limit pressure on the globe.

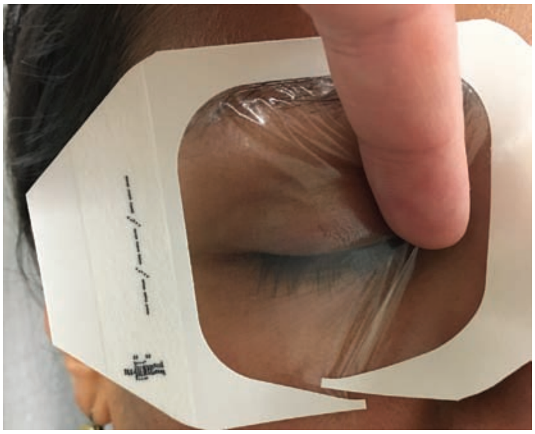


FIGURE 39.20 Tegaderm application.

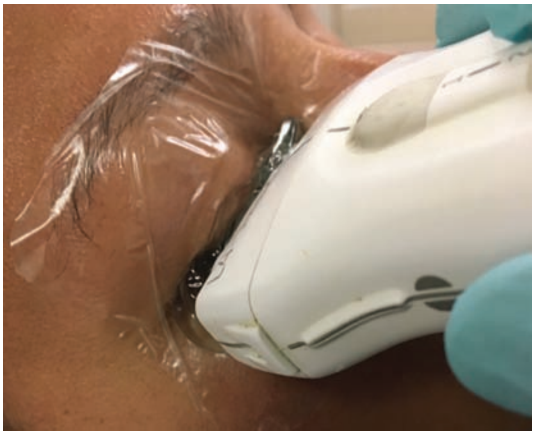
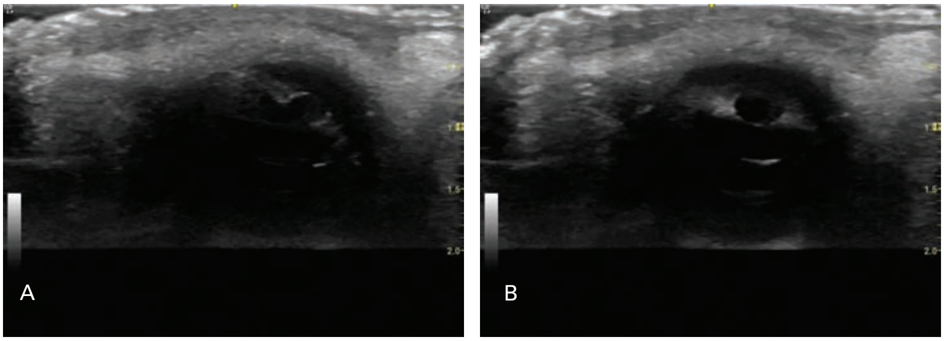


FIGURE 39.21 Sonographic technique.

PROCEDURE

- Hold the probe between your thumb and index finger, as you would a pencil.
- Rest your hypothenar eminence on the nasal bridge to enhance stability (**FIGURE 39.21**).
- If you stand to the left of the patient facing caudally, rest your hand on the patient's forehead.
- Instruct the patient to look straightforward.
- Position the probe in the transverse orientation.
- Scan fully from superior to inferior direction.
- Bring the probe back to neutral position and hold it in place.
  - To assess extraocular eye movement (EOM), instruct the patient to look left and right, and then upward and downward.
  - To assess consensual light reflex, place the probe on the inferior aspect of the eye and tilt upward to facilitate visualization of the pupil. Shine a light in the contralateral eye (**VIDEO 39.6**).
- Repeat with the probe in sagittal orientation.



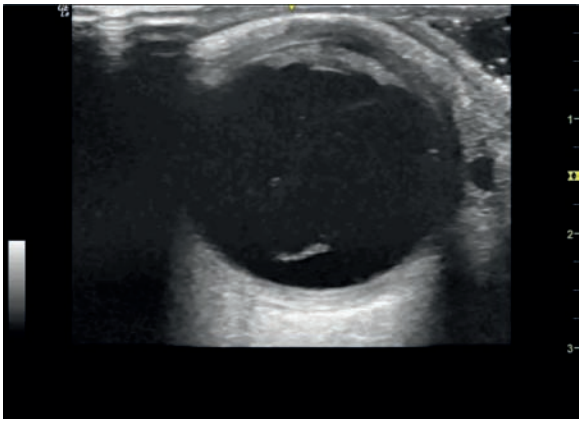
VIDEO 39.6 (A) Pupillary dilation. (B) Pupillary constriction.

POSTPROCEDURE CONSIDERATIONS

- None

EDUCATIONAL POINTS

- Adjust gain and depth to optimize image acquisition.
- Utilize color flow and Doppler to identify the central retinal artery and vein.
- When sonographically evaluating anterior structures, have the depth set to limit posterior viewing.
- Floaters may represent blood and/or vitreous strands in the posterior eye.
- In a retinal detachment, propagation occurs as vitreous fluid accumulates posterior to the tear, lifting (or detaching) the retina from the back of the eye.
- A quivering iris may be a symptom of lens dislocation due to the lack of lens attachment and support (**VIDEO 39.7**).
- Initial gain setting should be low, but expect to increase it during exam, especially when evaluating possible blood in the posterior or anterior chamber.
- The direct ophthalmoscope is insufficient for comprehensive examination because of the lower magnification and illumination, absence of stereopsis, and incomplete view of the retina.
- A physical exam finding of a full-thickness laceration to the cornea or sclera, evidence of extruded intraocular contents, or an irregular/teardrop pupil signifies an open globe perforation. An immediate ophthalmology consultation is thus in order.
- ONSD uses quantitative measurements that make the exam objective and allow you to compare ICP changes over time; it also detects increased ICP earlier than the presence of papilledema, as papilledema takes time to develop.



VIDEO 39.7 Lens dislocation.

COMPLICATIONS

- Applying an eye cover can minimize ocular irritation.
- Limit pressure when concerned about a possible globe rupture.

PEARLS

- Practicing and learning the US appearance of normal eye structures is key to confidently and rapidly diagnosing intraocular pathology.
- Visualize both eyes to allow suitable comparison.
- Use copious gel to minimize pressure on the globe.
- It behooves the reader to review the eye's basic anatomy and then learn its appearance on normal sonography; only then can bedside ultrasonography be utilized to quickly and competently ensure rapid eye pathology diagnosis.
- In regard to eye trauma, the clinician must maintain a high clinical suspicion for the diagnosis of globe rupture, as most cases are occult and the detection of *very* small scleral wounds are challenging to visualize, even for the astute clinician.
- Retinal tissue is stimulated by light and traction, so when the vitreous membrane separates from the retina or the retina tears, one experiences photopsia (the sensation of light).
- Any debris, speckles, or material seen sonographically in the vitreous humor is considered pathologic.
- Upon kinetic US eye examination, posterior vitreous detachment appears as congealed material tumbling about, similar to clothes in a dryer.
- In retinal detachment, time lost means photoreceptors, and hence vision, lost/loss.

- ICP elevation may be evaluated by measuring the ONSD 3 mm behind the eye. This may be interpreted roughly as follows:
  - Ophthalmoscopy is arduous, whereas ocular US is one of the easier skills to learn, given the eyeball is essentially a fluid-filled structure. In regard to ICP elevation, the clinician must be cognizant that the absence of an enlarged ONSD or elevated optic disc does not rule out intracranial pathology or elevated ICP. This application of ocular US should be used with caution and with a clear understanding of its limitations. High-risk patients with normal ocular US findings still warrant an appropriate workup, that is, CT or MRI. Furthermore, the data are very limited and of poor quality with respect to ONSD and papilledema.

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UNIT

XI

Procedures for Managing Common Nasal Conditions

CHAPTER 40

Procedures for Controlling Epistaxis

Leigh Anne Pickup

BACKGROUND

Epistaxis, or nose bleeding, is a common condition most often occurring in children less than 10 years of age and adults between 50 to 80 years of age. Bleeding is usually self-limited. Depending upon the source of bleeding, epistaxis is classified as anterior or posterior. This provides a useful foundation for determining management strategies. More than 90% of bleeding arises from the anterior portion of the nasal septum known as *Kiesselbach's plexus*. With the exception of trauma, anterior epistaxis is most often unilateral. Posterior bleeds typically occur along the nasal septum or lateral nasal wall and are more difficult to control. Compared to anterior bleeds, posterior epistaxis is more dangerous because of aspiration risk, difficulty controlling the bleeding source, increased risk of airway compromise, and risk for hemodynamic instability from blood loss. Posterior bleeding tends to be present in older patients and may cause bilateral epistaxis.

PATIENT PRESENTATION

- Bleeding from the nose and/or mouth
- Dizziness
- Skin may be pale and sweaty
- Nausea
- Anxiety

TREATMENT

Treatment for epistaxis requires identification of the bleeding source. Reassure the patient that identification of this source is imperative to proceed with any treatment measures. Management of epistaxis begins with conservative measures to control bleeding and transitions to more invasive measures to achieve hemostasis as necessary. Direct pressure, topical vasoconstrictors, vaso-occlusive therapy (silver nitrate or electrical cautery), nasal packing, and/or specialist treatment with endoscopic artery ligation and endovascular embolization are used as necessary.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Significant facial fractures with suspected or confirmed basilar skull fracture
- Airway obstruction
- Hemodynamic instability

SPECIAL CONSIDERATIONS

Anticoagulated patients are at an increased risk for epistaxis. Familial blood dyscrasias (platelet disorders, hemophilia, von Willebrand disease), hereditary hemorrhagic telangiectasia (Osler–Weber–Rendu disease), and tumors all increase patients' risk for epistaxis. There is increased risk of epistaxis in patients with hypertension but the data do not support a casual relationship. The association of aspirin and epistaxis is also unclear. There is no reported increased risk for epistaxis in patients taking nonsteroidal anti-inflammatory drugs.

PROCEDURE PREPARATION

- Personal protective equipment (gown, gloves, mask/eye shields)
- Frazier suction, irrigation, bayonet forceps, and nasal speculum
- Headlamp or adequate light source
- Absorbent pads
- Small or large basin
- Gauze
- Nose clip
- Cotton balls
- Vasoconstrictor (+/− with an anesthetic)
  - Oxymetazoline (Afrin) spray—vasoconstriction
  - 4% lidocaine spray—vasoconstriction
  - LET solution (lidocaine 4%, epinephrine 0.1%, and tetracaine 0.4%) applied to a cotton ball or gauze—vasoconstriction and anesthetic
  - Lidocaine 2% with epinephrine 1:1,000 applied to a cotton ball or gauze—vasoconstriction and anesthetic
  - 4% cocaine solution—vasoconstriction and anesthetic
- Silver nitrate cautery or electrical cautery
- Nasal packing/tampon/balloon (consider having at least two options)
  - Ribbon gauze impregnated with petroleum jelly
  - Commercially prepared product(s)
- Thrombogenic foams and gels
- Conformable, topical, hemostatic agents

PROCEDURE

- First and foremost, ensure that patient is hemodynamically stable and airway patency is achieved. If not, abort the procedure and obtain emergency airway stabilization as indicated.
- Place absorbent pad on the upright patient's chest and place a basin on the lap for use if patient spits up blood or as a place for soiled material.
- Have the patient blow the nose to remove any blood and clots that are obscuring the view of the nasal cavity. Use Frazier suction, irrigation, or bayonet forceps to remove blood and clots if necessary.
- Fully examine the nasal cavity to identify the source of bleeding. Use of a nasal speculum can be helpful for better visualization. Kiesselbach's plexus should be examined first. Next examine the vestibule, septum, and turbinates. If a bleeding source is not identified in these areas, a posterior bleed is suspected. Consider proceeding to nasal packing and obtaining specialist consultation.
- If an anterior source of bleeding is identified, and/or while gathering nasal packing materials, have the patient hold direct, firm pressure to the bilateral external nostrils against the septum for 10 to 15 minutes, without interruption, while tilting the head forward (to prevent swallowing of blood). A nose clip can be used if available and preferred.
- As an adjunct to compressive therapy, instill a vasoconstrictor (oxymetazoline) or a vasoconstrictor with an anesthetic (see earlier list).
  - Leave in for 10 to 15 minutes.
  - This often temporarily stops the bleeding, giving you a view of the culprit vessel for definitive hemostasis. This can be given prior to beginning compressive therapy if available.

Direct Vaso-Occlusive Therapy

If bleeding persists, or a prominent vessel is identified as the bleeding source, then proceed with *direct vaso-occlusive* therapy. This should only be used if the vessel/area of bleeding is visualized. Blind cauterization is contraindicated as ulceration and septal perforation can be caused by excessive destruction of the nasal mucosa. It is acceptable to repeat the earlier steps if necessary to better visualize the nasal mucosa.

- The simplest way to achieve direct vaso-occlusive treatment is by using silver nitrate cautery. It creates a chemical cautery when in contact with the moist nasal mucosa.
- Locate the vessel/area of the bleeding—direct visualization is imperative.
- Using one stick at a time, roll the tip, in a circumferential pattern, on the surrounding mucosa working to the site of bleeding until a gray/white eschar is formed. Do not apply directly to the site of bleeding first as brisk bleeding will wash away the silver nitrate. Apply the cautery for less than 10 seconds and never apply to both sides of the nasal septum because of the risk of septal perforation. Electrical cautery can be used in the same way if available.
- Be sure to tell the patient that they may need to sneeze, so have the patient turn their head away from you and sneeze through the mouth. Also, inform the patient that the cautery causes a burning pain sensation in the area of application. This is where it is nice to use anesthetic if possible.

If hemostasis is achieved, monitor the patient for 30 minutes for recurrent bleeding. If none occurs, it is then appropriate to discharge for outpatient follow-up.

Nasal Packing/Tampon/Balloon

If silver nitrate is unable to achieve hemostasis, the site of bleeding cannot be located or visualized, or the bleeding is too diffuse, the next step is some type of *nasal packing/tampon/balloon*. Pretreatment with a topical anesthetic and topical vasoconstrictor is quite helpful.

- Traditional nasal packing involves layering ribbon gauze, impregnated with petrolatum, starting at the base of the nasal cavity and layering to the top. This completely compresses the nasal cavity but is quite time-consuming (**FIGURE 40.1**).
- Commercially prepared products, such as nasal tampons and balloons, accomplish the same compression but are easier to use, assuming they are readily available.

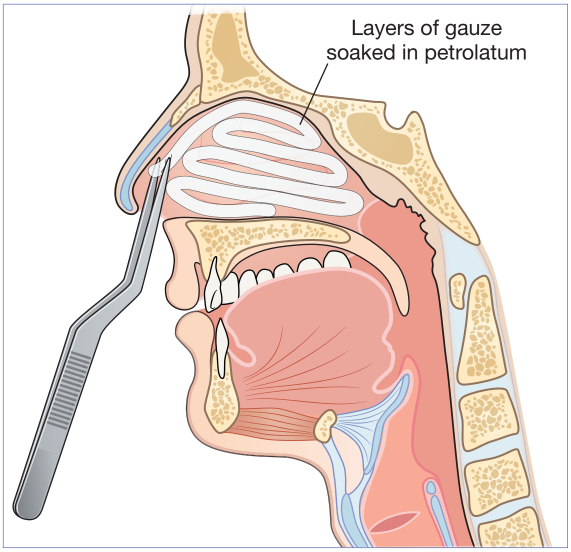

FIGURE 40.1 Traditional nasal packing layering method.

Commercially Prepared Devices

Prior to instillation, dry packing devices should be coated with antibiotic ointment rather than placing them dry. This helps with comfort and possibly decreases the risk of toxic shock syndrome. Product directions should be closely followed as some require soaking the catheter in sterile water for 30 seconds rather than using lubricant. Avoid using petroleum-based lubricant on devices with a balloon as it can degrade the rubber. Once the product is prepared,

- With slow, gentle pressure, insert the device into the naris on a horizontal plane, directly along the floor of the nasal cavity, until nearly the entire device is inside the nasal cavity.
- If the device has a balloon (**FIGURE 40.2**), have the patient tell you when they begin to feel the pressure as you inflate; that is when you stop. Too much pressure can lead to pressure necrosis of the septum.
- If the device does not have a balloon, infuse approximately 10 mL of saline into the nasal cavity to help expand the device inside the nares.
- After the device is placed, examine the posterior pharynx.
- Some blood behind the uvula is normal, and should stop flowing. A constant flow of blood, however, suggests a posterior bleed. If this is present, consider obtaining specialty consultation.
- Although some commercial devices control posterior bleeds, patients requiring these should be admitted to the hospital and managed by specialty consultants. Definitive control of posterior bleeding is not addressed in this chapter.

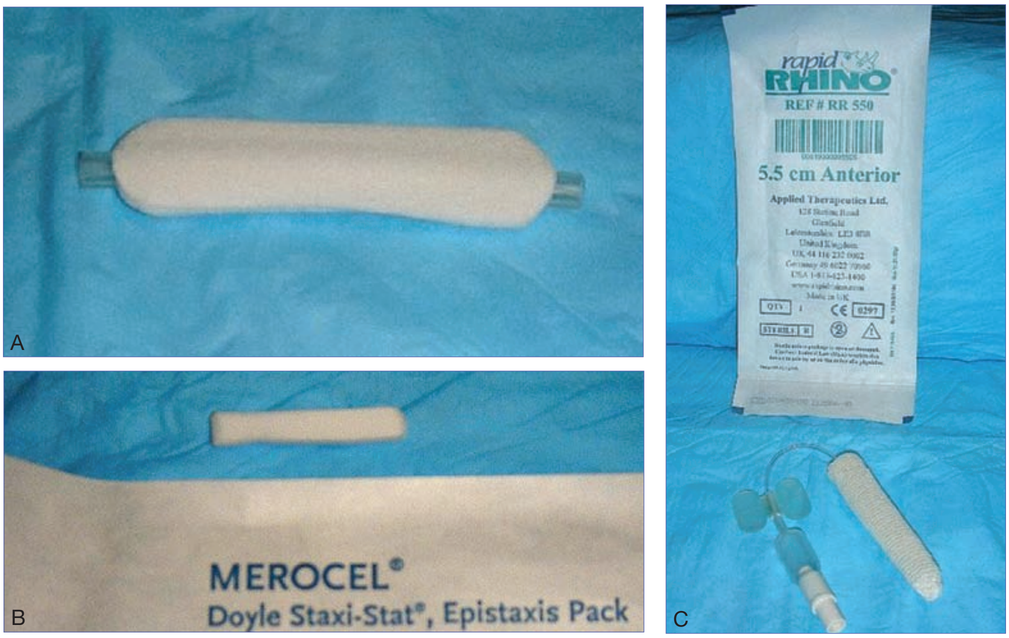

FIGURE 40.2 Commercially available inflatable balloons. This Rhino Rocket product is composed of an inflatable balloon coated with a carboxymethylcellulose hydrocolloid compound that acts as a platelet aggregator and also forms a lubricant on contact with water.

Thrombogenic and Hemostatic Agents

Thrombogenic foams and gels, as well as conformable, topical hemostatic materials, are available at some institutions. Their use is ideal when attempting to avoid nasal packing. Thrombogenic foams and gels require mixing a thrombin powder with the saline diluent prior to use.

- After it is drawn up in a syringe, a special nasal drug delivery device is attached.
- The contoured tip is inserted into the naris, and the solution is sprayed as a fine mist across the nasal mucosa. Follow instructions supplied with the material.
- The tranexamic acid (TXA) method requires cotton packing to be soaked in TXA and then inserted into the nose as nasal packing. It is removed when bleeding stops. When used with anterior epistaxis, cessation of bleeding most often occurs quickly (under 10 minutes) and has lower rates of rebleeding compared to traditional anterior nasal packing.

Conformable, topical, hemostatic materials can be trimmed, using iris scissors, to an appropriate size and then applied to the site of bleeding. These are most effective in anterior bleeds where the site of bleeding is visible. Follow instructions contained with the material. If these products do not result in hemostasis, nasal packing should be utilized.

POSTPROCEDURE CONSIDERATIONS

- Antibiotic prophylaxis
    - Though used frequently, evidence is lacking to support prophylactic antibiotic coverage in patients with nasal packing to prevent toxic shock syndrome, sinusitis, or acute otitis media. Therefore, routine oral antibiotic coverage is discouraged unless the patient is at a greater risk of infection based on history or special circumstances.
- Refer to an otolaryngologist for packing removal in 1 to 2 days.
    - If no packing was placed, lubricate the nasal mucosa with antibiotic ointment, three times per day for 3 days, and encourage outpatient follow-up within 24 to 48 hours or sooner if rebleeding occurs.

EDUCATIONAL POINTS

- Ninety percent of epistaxis is anterior and can be managed with direct pressure, vasoconstrictive medication, and/or cautery.
- If bleeding does not resolve it is appropriate to resort to nasal packing. The use of nasal tampons or balloon catheters is easier to apply and better tolerated than the past method of gauze packing. Regardless, the treatments are equally effective for hemostasis.
- Posterior epistaxis is more dangerous and can require deeper packing and specialty evaluation along with hospital admission.
- All patients with epistaxis need close follow-up and encouragement to return sooner if recurrent bleeding occurs.
- Keeping the nasal mucosa moist is a key to preventing recurrent epistaxis.

COMPLICATIONS

- Hemodynamic instability

PEARLS

- It is imperative to determine whether the bleeding is occurring from an anterior or a posterior source.
- Prior to beginning your evaluation of the nasal cavity, ensure that the nasal cavity is clear of blood and clots. This will increase the likelihood of finding the source of bleeding.
- Become familiar with several different methods to obtain hemostasis in the likely event that one method is not successful.

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CHAPTER

41

Procedures for Removing Nasal Foreign Body

Leigh Anne Pickup

BACKGROUND

The presence of a nasal foreign body is usually a problem in young children, as adults are rarely leaving objects deep in their noses (except for psychiatric and mentally disabled adults). The history given by a parent or a caregiver, and/or the presence on evaluation of significant unilateral nasal discharge, should prompt a search for a foreign body.

Nasal foreign bodies can be organic or inorganic; they are commonly toys, beads, paper, nuts, and food. Foreign bodies that obstruct the nasal cavity, button batteries, and magnets compressing the nasal septum must be removed emergently. Otherwise, removal of a nasal foreign body is an elective procedure. An experienced clinician with proper equipment, lighting, and patient cooperation has the best likelihood for successful removal of the foreign body.

PATIENT PRESENTATION

- Pain
- Discharge
- Visible foreign body
- Anxiety

TREATMENT

Most intranasal foreign bodies can be removed. The positive-pressure technique is best used in patients with soft or smooth foreign bodies that completely occlude the anterior nasal cavity. If the foreign body is nonocclusive, nonspherical, and able to be visualized, then direct instrumentation techniques are recommended. Some food, such as candy, usually dissolves before removal is possible; therefore, it will not be visualized. Specialty referral is indicated for the following types of nasal foreign bodies:

- Obstruction of the nasal cavity (emergent referral)
- Button batteries (emergent referral)
- Magnets compressing the nasal septum (emergent referral)
- Object not easily visualized
- Hooked or penetrating
- Unable to be removed by use of positive pressure or direct instrumentation

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

None.

SPECIAL CONSIDERATIONS

Procedural sedation and sometimes specialist intervention in the operating room/short procedure unit are required to remove deep objects and/or objects that cannot be removed using traditional techniques.

PROCEDURE PREPARATION

- Nasal speculum
- Good lighting—headlamp preferred
- Direct instrumentation devices:
  - Bayonet forceps, alligator forceps, right-angle hook, and/or ear loop
  - Schuknecht catheter with suction at 100 to 140 mmHg
  - 5- to 8-French indwelling urinary catheter and/or commercially prepared balloon extractor
  - Cyanoacrylate glue and a cotton-tipped applicator
  - Vasoconstrictor (e.g., oxymetazoline)
  - Topical anesthetic (e.g., 4% lidocaine spray)
  - Sheet for wrapping or an immobilization device accepted by your facility

PROCEDURE

- Good lighting (either with an assistant holding a flashlight, good overhead lighting, or a headlamp) provides the most optimal conditions for visualization/location of the foreign body within the nasal cavity.
- If the foreign body is immediately visualized proceed with the appropriate technique—positive pressure or direct instrumentation. If it is not visualized, proceed with the use of the nasal speculum.
  - The proper way to hold the nasal speculum is to insert it into the naris with the handles horizontal (parallel to the floor). This allows the best visualization of the entire nasal cavity (**FIGURE 41.1**).
- If there is too much nasal discharge or bleeding, use of a vasoconstrictor, such as oxymetazoline, helps dry the naris of blood and/or mucus to allow for better visualization.
- Topical anesthesia (lidocaine 4%) is helpful for patient comfort and cooperation. This can be provided 5 minutes prior to beginning the procedure or when it is deemed necessary after beginning the procedure.
- Last, if patient cooperation is not optimal, use of short-term restraints might be beneficial. Use techniques approved by your facility to temporarily restrain your patient. Enlisting the help of the parents/caregivers, if your patient is a child, not only provides needed restraint but also comfort to the child.
- If the visualized foreign body is soft, smooth, and completely occluding the nasal cavity, proceed with *positive-pressure techniques* (described as follows).
- If you are able to visualize the object, and it is not occluding the airway, then proceed with a *direct instrumentation technique* (described later) using bayonet forceps, Schuknecht catheter, alligator forceps, right-angle hook, an earwax removal tool "ear loop" (with the tip bent at 90 degrees), a catheter, or a Katz extractor to remove the foreign body (**FIGURE 41.2**).

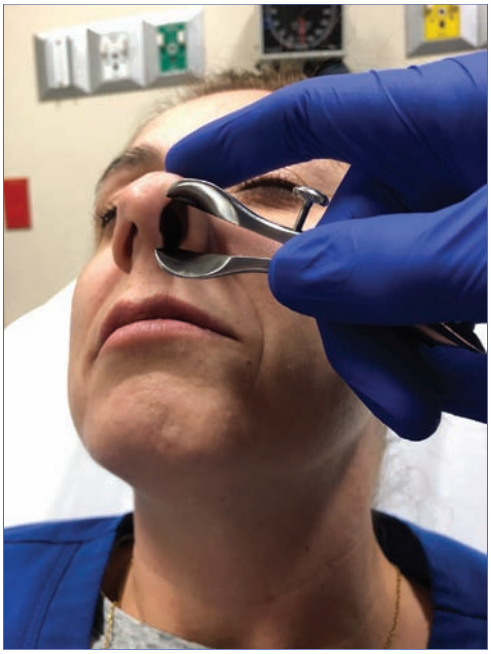

FIGURE 41.1 Proper use of nasal speculum for optimal visualization.

Positive-Pressure Techniques (Patient vs. Parent Assisted)

Although the *patient-assisted positive-pressure technique* is the easiest method, it is only applicable to patients who are older than 3 years and cooperative. It involves the patient blowing their nose while occluding the uninvolved nostril.

The *parent-assisted technique* ("parent's kiss") utilizes the parent's help for removal. It works better with larger objects (beans, large beads, etc.).

- Inform the parent that it may get a little "messy" when the object is expelled. Having an absorbent pad on the patient's chest is helpful.
- With the patient being held by the parent (supine), have the parent occlude the unaffected naris and blow a strong puff into the patient's mouth (**FIGURE 41.3**).
- This will often result in the object being expelled from the naris.

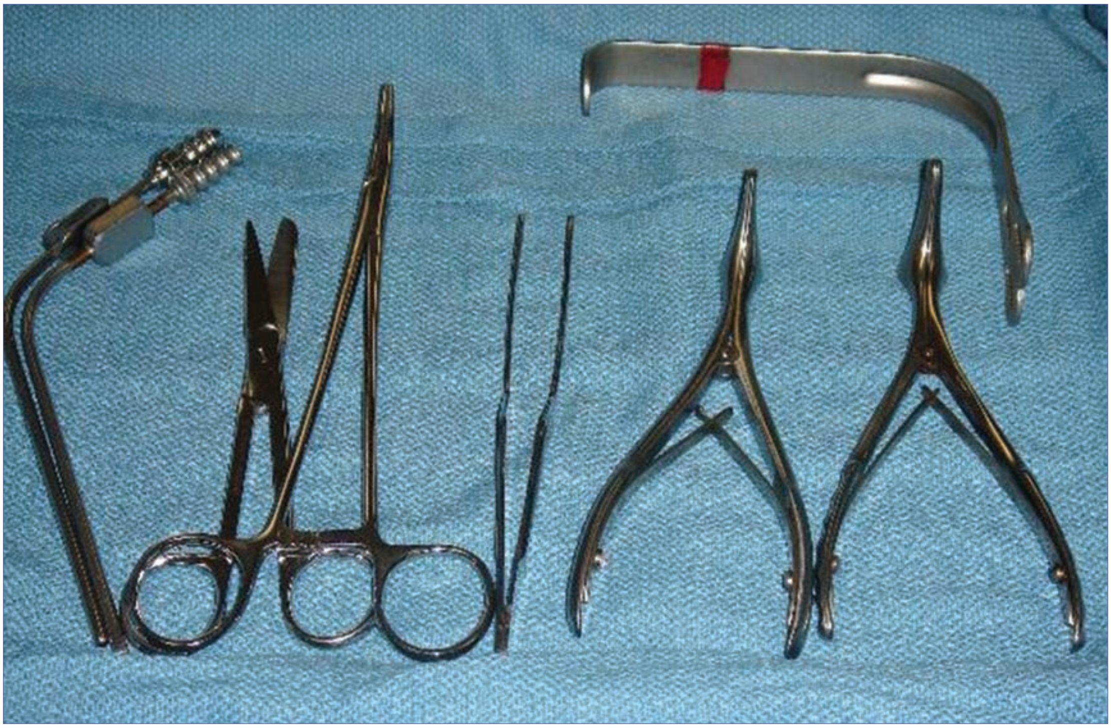

FIGURE 41.2 Instruments used for direct removal techniques.

Source: Goralnick E. (2018). Anterior nasal packing for epistaxis. In A. D. Meyers (Ed.), *Medscape*. Retrieved from https://emedicine.*medscape*.com/article/80526-overview. Reproduced with permission from Medscape.

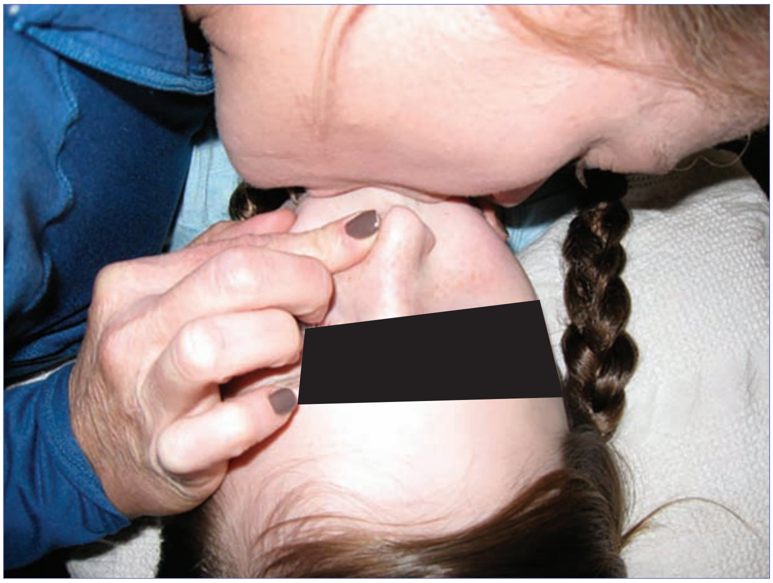

FIGURE 41.3 Parent's kiss method.

Direct Instrumentation Techniques

REMOVAL WITH INDWELLING URINARY CATHETER AND/OR COMMERCIALLY MADE BALLOON EXTRACTOR: NOTE THAT THIS CAN BE USED FOR FOREIGN BODIES IN THE EAR AS WELL

- Apply vasoconstrictor and topical anesthetic in the affected naris 5 minutes prior to procedure.
- Use the parent, medical staff member, or approved techniques to restrain the patient prior to attempting retrieval of the foreign body.
- Slide the lubricated (using water-soluble lubricating jelly) tip of the catheter into the naris beyond the object.
- Slowly inflate the balloon with approximately 2 mL of air or water. If using a commercially made balloon extractor, inflate with 1 mL of air using the syringe attached to the extractor.
- Slowly withdraw the catheter with the balloon inflated, thereby removing the object (**FIGURE 41.4).**

CYANOACRYLATE GLUE SKIN ADHESIVE/GLUE

- Be sure the naris is as dry as possible (using the vasoconstrictor).
- Use the parent, medical staff member, or approved techniques to restrain the patient prior to attempting retrieval of the foreign body.
- Place a drop of adhesive on the wooden tip of a cotton-tipped applicator.
- Touch the foreign body with the wooden end and leave in place for 60 seconds. Then gently pull out of the naris. The foreign body will be removed by staying attached to the wooden end of the applicator (**FIGURE 41.5**).

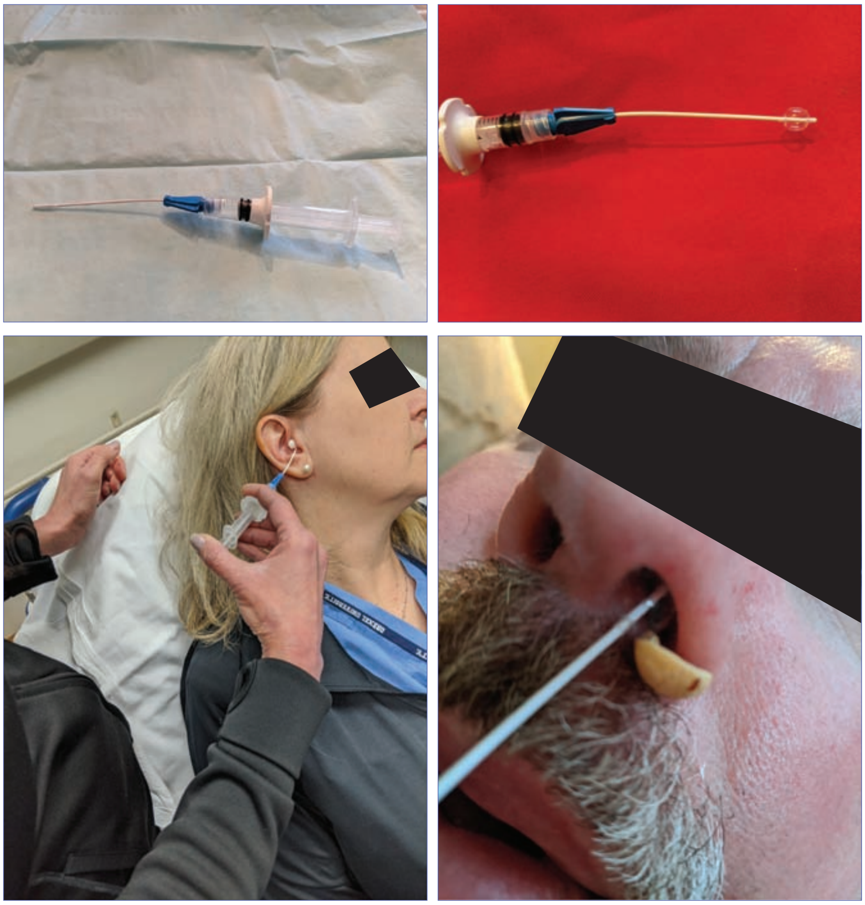

FIGURE 41.4 Foreign-body removal with balloon extractor. Note that this method can be used for foreign bodies in the ear as well.

BAYONET FORCEPS, ALLIGATOR FORCEPS, RIGHT-ANGLE HOOK, AND/OR EAR LOOP

- Each instrument serves a more optimal purpose than another depending on the type of foreign body encountered and clinician preference. In general, nonobstructing smooth objects are best removed using the right-angle hook or the ear loop. Compressible objects are best removed using bayonet or alligator forceps as these can be grasped.
- Slide the lubricated (using water-soluble lubricating jelly) instrument (if needed) into the naris, positioned as appropriate for the selected instrument to grasp the object.
- Slowly withdraw the instrument, thereby removing the object.

SCHUKNECHT CATHETER WITH SUCTION AT 100 TO 140 mmHG

- This instrument is helpful when attempting to remove a nonobstructing, smooth, round, solid object as the plastic umbrella tip and suction work to grasp the object for removal.

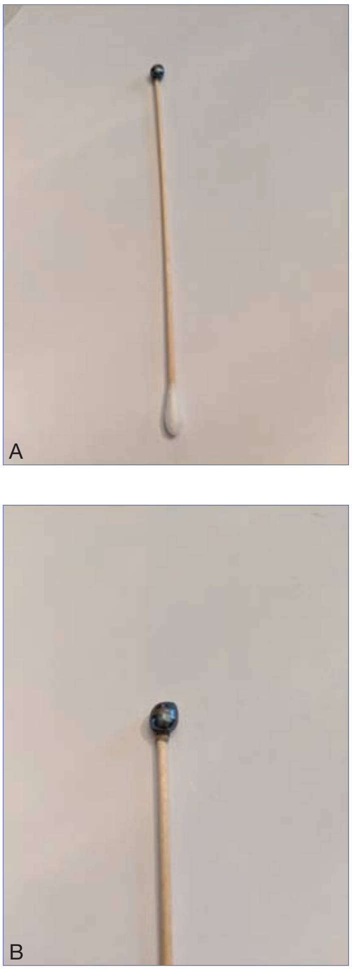

FIGURE 41.5 Using glue to remove a foreign body. (A) Cyanoacrylate glue on applicator. (B) Close-up view of glue.

POSTPROCEDURE CONSIDERATIONS

- After the object is removed, inspect the entire nasal cavity to ensure no foreign body remains. Address any epistaxis that results from the procedure.
- Reassure patient and any family members present that the foreign body has been removed and the procedure was successful.
- Discuss referral to a specialist if the object could not be removed.
- Discuss the importance of follow-up and expected time until reevaluation (and with whom that should occur).

EDUCATIONAL POINTS

- Unilateral foul-smelling nasal discharge in a young child/toddler indicates the presence of a nasal foreign body until proven otherwise.
- Only remove a foreign body if it is visualized. NO blind attempts should be attempted.

COMPLICATIONS

Minimal epistaxis can be expected during and after the procedure—control as indicated.

PEARLS

- Good light and full cooperation of the patient are necessary for successful removal of the nasal foreign body. Note that restraint of a child or procedural sedation may be necessary.
- Evaluate whether the foreign body is occluding the anterior nasal cavity. Evaluate the consistency of the foreign body to choose the best technique for removal. Note that it may be necessary to attempt more than one technique. If unsuccessful, refer to a specialist for removal.

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UNIT XII

Procedures for Managing Common Ear Injuries

CHAPTER 42

Procedures for Cerumen Removal and Ear Foreign-Body Removal

Kelley Toffoli

BACKGROUND

Cerumen, or earwax, is a naturally occurring hydrophobic protective covering composed of lipids, complex proteins, and sugars, which is responsible for moisturizing the auditory canal. In addition, cerumen repels water in the auditory canal and protects from trauma and foreign bodies (Schwartz et al., 2017). It is considered to be bactericidal and fungicidal, as it also protects from infection. Despite its helpful properties, cerumen obstruction or impaction of the external auditory canal is a common problem, often occurring when cotton-tipped applicators are used to clean the ears, pushing the cerumen deep into the ear canal. Patients usually present for treatment when they experience a “clogged” sensation, decreased or loss of hearing, fullness, and/or dizziness feeling as a result of a blocked tympanic membrane.

Cerumen may partially or completely block the tympanic membrane and should be removed for a complete and thorough examination of associated structures. Cerumen removal in the ED is often not required; asymptomatic or minimally symptomatic patients with cerumen impaction may be safely discharged home with a cerumen-softening otic solution and follow-up (Vrablik, 2018). Indications for cerumen removal include reduced hearing, difficulty visualizing tympanic membrane, cerumen impaction, and debris removal associated with otitis externa.

PATIENT PRESENTATION

- Fullness in ear
- Blocked or clogged sensation
- Dizziness
- Reduced hearing or loss of hearing
- Tinnitus
- Painless; if pain present, suspect other origin (i.e., infection or perforation)

TREATMENT

The most commonly and easily performed methods for cerumen removal are use of a curette or warm-water irrigation. Manual removal with a curette is a simple procedure used to remove hard cerumen or large pieces. However, this can be painful to the patient. Warm-water irrigation is painless, easy, and more often used.

Ceruminolytic agents can also be used to soften and aid in the removal of cerumen. There are three types of ceruminolytic agents: water-based, oil-based, and nonwater-/nonoil-based. These agents can be used alone or as pretreatment for curette or water irrigation removal.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- History or suspicion for perforated tympanic membrane, severe canal swelling
- Previous pain with irrigation
- Previous surgery to middle ear

- History of middle ear disease
- Sharp or organic foreign bodies
- Tinnitus
- Vertigo
- Radiation therapy to external or middle ear, skull base, or mastoid
- Patient with a history of mastoidectomy and hypersensitivity of the underlying structures

SPECIAL CONSIDERATIONS

- Patients who have previous surgery to the middle ear or mastoidectomy require consideration.
- Diabetic patients should be carefully evaluated for the development of otitis externa after any manipulation of the ear and/or canal.
- Irrigation should never be performed if a ruptured tympanic membrane is suspected or confirmed.
- Jet irrigators can be used but care should be given not to rupture the tympanic membrane.

PROCEDURE PREPARATION

- Curette or flexible plastic or wire-loop curette or plastic scoop
- 3-mm or 9-gauge Frazier cannula vacuum suction with closed orifice pressure relief valve by finger occlusion
- Gauze pads

Warm-Water Irrigation

- Large-volume syringe (30–60 mL) or ear irrigator tip and syringe
- Large-gauge angiocatheter with needle removed (16 or 18 gauge)
- Warm water or normal saline
- Hydrogen peroxide
- Kidney basin
- Absorbent pad
- Towels

Light Source

- Otoscope or headlamp

PROCEDURE

Curette

- Gently straighten the canal by pulling the pinna back and upward (downward for children).
- Visualize the canal and wax with the otoscope.
- *Gently and slowly* insert the loop curette and remove the cerumen (**FIGURE 42.1**).

Suction-Tip Catheter

- Aural suction-tip catheters can be an effective means to assist with evacuation of cerumen.
- Visualize the canal and wax with the otoscope.
- *Gently and slowly* insert the suction catheter into the outer end of the auditory canal, occlude the suction orifice to activate suction mechanism to draw cerumen from the canal.

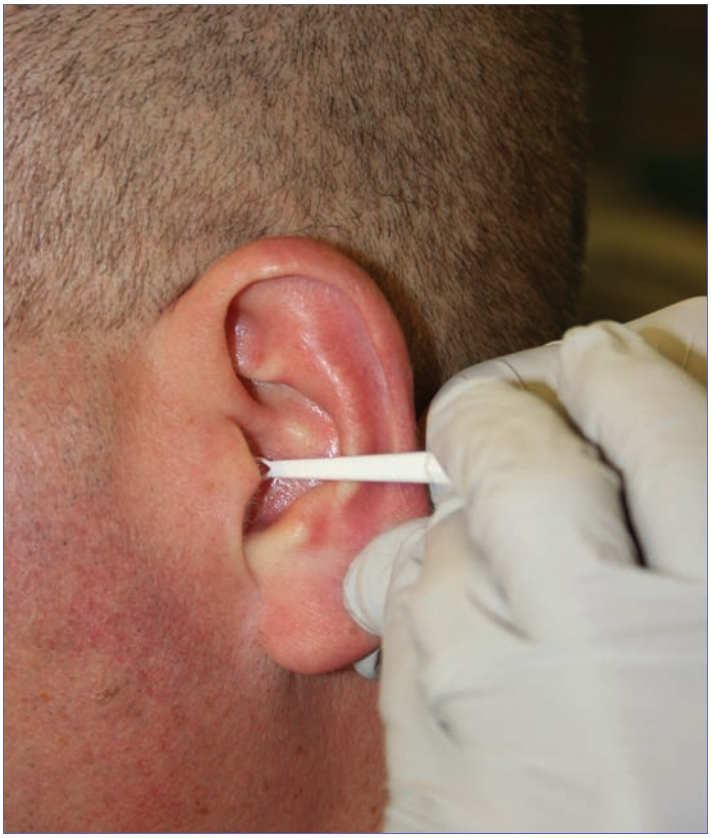

FIGURE 42.1 Photograph showing cerumen removal with curette.

Warm-Water Irrigation

- Place an absorbent pad over the patient's shoulder.
- Have the patient sit up with the kidney basin below the ear and held snug against the neck to prevent water running down onto the neck and shoulders.
- Visualize the canal and wax with the otoscope.
- Fill the syringe with warm water. Use warm water to prevent discomfort and dizziness.
- Mix warm water and hydrogen peroxide (1:1 concentration).
- Gently straighten the canal by pulling the pinna back and upward (downward for children).
- Have the patient tilt their head so that the affected ear is facing the ground.
- Place the tip of the catheter at the opening of the canal. The tip should not be placed past the lateral one-third of the ear canal.
- Instill the water gently and then allow it to run into the kidney basin (**FIGURE 42.2**).
- Repeat the irrigation until the cerumen is removed or the patient verbalizes complaints of pain, vertigo, and so on.
- Use the curette to help remove cerumen that is pushed to the canal entrance.
- Once completed, instill several drops of hydrogen peroxide in the canal to evaporate any residual moisture and prevent infection.

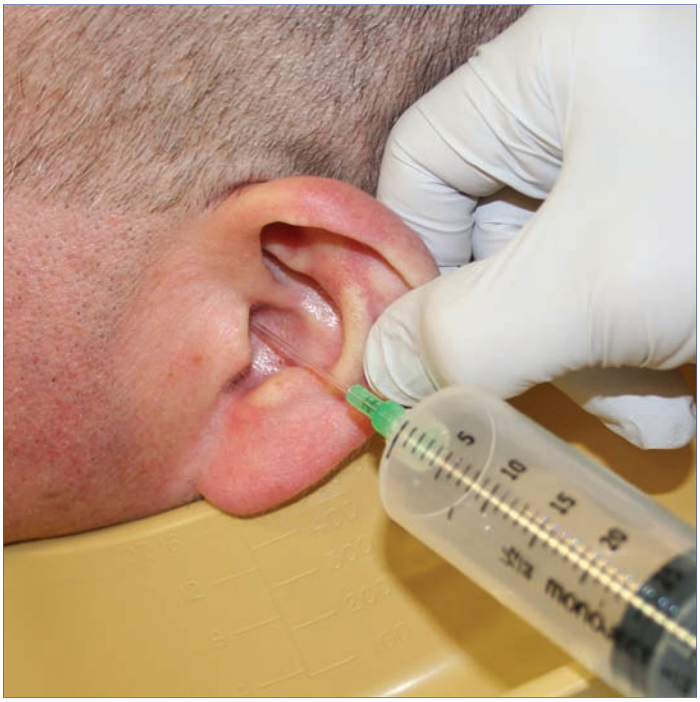

FIGURE 42.2 Photograph showing cerumen removal with warm-water irrigation.

POSTPROCEDURE CONSIDERATIONS

Pain

- The ear is very sensitive to pain.
- Topical ear drops, such as antipyrine and benzocaine, can be given for pain relief.

Tympanic Membrane

- Visualize the tympanic membrane to be sure it is intact and not perforated.

Vertigo

- Have the patient lie down until the dizziness resolves, which usually takes a few minutes.
- If the vertigo persists, a short dosing period of antivertigo medications, such as meclizine, can be prescribed.

Ear Canal Abrasion and/or Irritation

- Instillation and prescription of topical ear drops (i.e., fluoroquinolones) can be prescribed for the patient for a few days to help prevent infection and soothe the ear.

EDUCATIONAL POINTS

- Do not use cotton-tipped applicators inside the ear canal.
- Encourage regular checkups with the primary care clinician for evaluation and irrigation.

COMPLICATIONS

- Complications arising from either curette or irrigation are usually benign and of brief duration.
- Patients with diabetes or immunosuppression should be treated with a short regimen of topical antibiotic ear drops (i.e., fluoroquinolones) for 7 days (Gilbert, Chambers, Eliopoulos, Saag, & Pavia, 2019).

PEARLS

- Always perform and document your evaluation before and after removal, including removal failure.
- Have the patient assist in the removal by holding the basin and turning the head.
- Suction-tip catheters can aid in the removal of the cerumen. Aural suction can be utilized to draw cerumen from canal. Use with caution in children.
- Pretreatment with ceruminolytics can help with easy and quick removal of cerumen.
- A mixture of warm water and hydrogen peroxide (1:1) can be used prior to irrigation. Have the patient lie on the unaffected side with the ear facing the ceiling for 5 to 10 minutes prior to irrigation. If a patient presents with a chronic dry cough that is not resolving, check the external canal for a foreign body. It may be pressing on the 10th cranial nerve, causing the cough.

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CHAPTER 43

Procedures for Foreign-Body Removal From the Ear Canal and Lobe

Lia V. Ludan

BACKGROUND

Foreign bodies in the external auditory canal (EAC) are common complaints seen more often in children, although adults can be affected as well. Some commonly lodged foreign bodies are insects, cotton, beads, toys, rocks, popcorn kernels, erasers, batteries, and Bluetooth devices. Insects seem to be the most common foreign body found in the ear.

Timely removal of button batteries and magnets from the EAC is vital. Damage to tissue, facial nerves, and even hearing loss can occur if removal is delayed. Immediate referral to an otolaryngologist should occur for button batteries or magnets that cannot be removed. Foreign bodies that are detected in the medial canal should also be referred to an otolaryngologist. Due to the location of sensory fibers, foreign bodies located in the lateral canal are more easily removed than those in the medial canal.

Foreign bodies that occur in the pinna of the ear are usually the result of embedded pierced earrings. These can be located at the ear lobe or the cartilaginous section of the pinna. Patients will complain of pain, swelling to the site, redness, and possibly purulent drainage. The back of the earing typically will not be visible on inspection.

The presence of perichondritis and chondritis can occur from piercing through the cartilage. If this is noticed, then oral antibiotics should be started. The antibiotics should cover *Staphylococcus aureus* and *Pseudomonas aeruginosa*. These infections should be seen by an otolaryngologist.

PATIENT PRESENTATION

- Pain
- Feels something moving around, hears a buzzing noise
- Caregiver or patient concerned about EAC foreign body
- Decreased hearing, fullness
- Drainage from ear
- Dizziness
- Cough

TREATMENT

Removal of foreign bodies from the ear can be approached in various ways. The clinician should select the removal method based on the type of foreign body that is present. When removing dirt, sand, and small objects lying near the tympanic membrane, irrigation is most helpful. Irrigation, however, is contraindicated when removing magnets, button batteries, or objects that may swell (such as paper, seeds, or vegetables). For objects with smooth, rounded edges that are difficult to grab, a suction tip catheter can be used. Due to the oval shape of the ear canal, these objects become lodged easily. Curettes and angel hooks can be used to retrieve small objects that do not completely occlude the canal. Alligator forceps can be used if the item can be grabbed easily, such as insects, paper, or cotton. Dry items in the lateral canal can be removed by using glue (cyanoacrylate).

Regardless of technique, foreign-body removal can be distressing to patients, especially children. Before removal, the procedure should be explained to the patient and any family members. Limiting the number of attempts will aid in decreasing pain, anxiety, or a traumatic removal.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Lack of appropriate tools
- Uncooperative patients and the inability to safely sedate patient
- Irrigation should not be performed if suspected or confirmed tympanic membrane rupture or perforation, or in the presence of tympanostomy tubes

SPECIAL CONSIDERATIONS

- Consider conscious sedation or referral to an otolaryngologist to avoid traumatic removal.
- If patients are anxious, clinician may need one or more assistants.

PROCEDURE PREPARATION

- Gloves
- Gauze pads
- Absorbent pads
- Light source (overhead light, headlamp, or otoscope)

Manual-Removal Technique

- Curette loop or scoop
- Alligator forceps

Suction-Tip Catheter Technique

- Suction-tip catheter with small hole for thumb control (Frazier suction); suction tubing attached to wall suction

Glue (Cyanoacrylate) Technique

- Cotton-tip applicator or paper clip
- Glue

Insect Removal

- Mineral oil
- Lidocaine solution (2% or 4%)
- Alligator forceps and/or curette

PROCEDURE

Most often, the patient should lie supine with affected ear up. The ear canal should be straightened by gently retracting the pinna back and upward in adults. If the patient is a child, then pull pinna downward.

Manual Removal

- Visualize the canal and foreign body, utilizing otoscope as necessary. Do not attempt a blind removal.
- Insert the loop curette/forceps *slowly and gently* to remove the foreign body. The curette should be rotated to pass behind the foreign body, then used to gently pull it out of the canal (**FIGURE 43.1**).

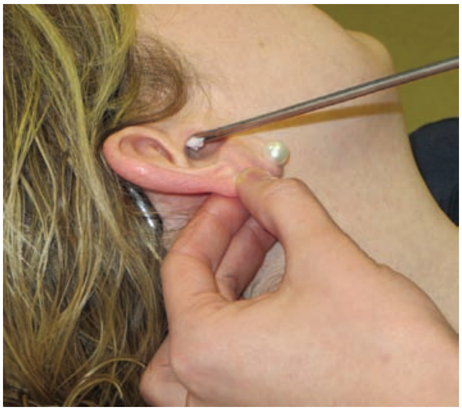

FIGURE 43.1 Manual removal of a foreign body from the ear.

Suction-Tip Catheter

- Patient may be positioned supine with affected ear up or patient can be sitting upright.
- Inform the patient of the noise associated with the suction device. Allowing the patient to hear the noise prior to the procedure can decrease anxiety or fear of the procedure.
- Set the suction between 100 to 140 mmHg.
- Place the suction tip onto the object and gently pull the object out of the EAC. Be careful to keep the tip away from the canal walls (**FIGURE 43.2**).

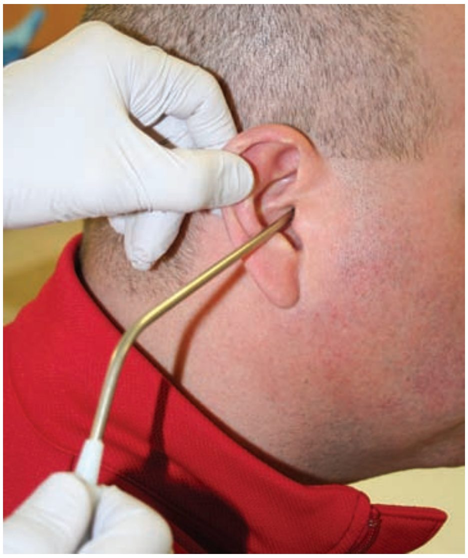

FIGURE 43.2 Foreign-body removal from the ear with a suction-tip catheter.

Glue (Cyanoacrylate)

- Apply glue to the end of a straightened paper clip, or wooden end of a cotton-tip applicator.
- Once the glue is tacky, straighten the pinna of the ear as described previously and place the tip against the object. Wait 60 seconds, and then gently pull out the object.
- This procedure requires patience and precision, as well as a cooperative patient who will lie very still to prevent adherence of the glue to the canal. Care must be taken to avoid contact with the EAC during the procedure.

Insect Removal

- Prior to removal, the insect must be dead. If still moving or alive, mineral oil or lidocaine (2% or 4%) should be instilled in the ear canal.
- Once the insect is dead, it can be removed with alligator forceps and or curette as described earlier.

Earring Back in Earlobe

- Clean the area with alcohol or iodine.
- Use sterile technique in the event that an incision is necessary for removal.
- The part of the earring that is embedded will direct the clinician's removal process.
- If the post backing is embedded with the front of the earring visible, the clinician should apply posterior pressure to the front of the earring until the backing is visible behind the pinna.
- Remove the backing posteriorly, and the post anteriorly. Hemostats may be used for additional grip.
- If this technique fails, an incision should be made to the posterior pinna where the earring is embedded.
- Gently spread the skin with a hemostat until the back of the earring is visible. Clamp the backing with the hemostat and remove from the post as explained earlier.
- If instead the earring is embedded with the back invisible, the clinician will push the backing anteriorly until the post is visible. Then remove earring as described earlier.
- If this technique fails, then the clinician will make a small incision to the posterior pinna, use hemostat to spread the skin until the post is visible, clamp the earring, and remove.
- Wound should be irrigated with normal saline, and antibiotic ointment may be applied.

POSTPROCEDURE CONSIDERATIONS

- Abrasions or lacerations from EAC foreign-body removal usually heal without complications.
- Antibiotic ear drops may be used to help prevent infections but have not been proven necessary or effective.

EDUCATIONAL POINTS

- Children, adults with special needs
  - Teach not to put any objects in the ears, nose, or any other "holes" in their bodies.
- Adults
  - Instruct not to clean ears with cotton-tipped applicators.
- Insects
  - Insects may just fly into the EAC, especially during the warmer months.
  - An evaluation of the home by pest control should be advised for patients who develop lodged insects in the EAC while in the home or sleeping.
- Earring
  - Earrings should not be replaced until wound has completely healed.

COMPLICATIONS

- Tympanic perforation, rupture, or excoriation may result from the foreign body itself or from the removal.

PEARLS

- Make sure you have adequate lighting, tools, personnel, and patient cooperation to ensure successful removal of the object.
- Minimizing the number of attempts can reduce the risk of rupture or perforation of the tympanic membrane.
- Always evaluate the other ear and the nose for the presence of additional foreign bodies.
- Always document your evaluation before and after procedure. Document number of attempts and removal failure.
- A dry, chronic cough could be caused by a foreign body in the external canal that is pressing on the 10th cranial nerve.

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CHAPTER

44

Procedures for Managing an Auricular Hematoma

Theresa M. Campo and Julia McDonald

BACKGROUND

An auricular hematoma occurs from direct, blunt trauma to the ear, causing a shearing force. It is commonly seen in wrestlers, rugby players, and mixed martial arts competitors. It may also occur after an assault or altercation. The shearing force to the anterior auricle disrupts the tight adherence between the vascular perichondrium and the avascular cartilage. This trauma causes blood or serum to form a layer between the perichondrium and the cartilage, forming the hematoma. Separation of the perichondrium from the cartilage leads to devitalized cartilage, which has a propensity to develop new chaotic cartilage formation, ultimately causing a permanently deformed ear. This deformity is called “cauliflower ear” or “wrestler’s ear.” Prompt treatment following injury is required to minimize the risk of the development of cauliflower ear, infection, cartilage necrosis, and contracture. Use of protective head gear while participating in contact sports, such as wrestling, rugby, and mixed martial arts, can minimize the risk of this injury from occurring. Protective headgear, however, has not been well accepted by these athletes, who often avoid treatment as they consider a cauliflower ear to be a “badge of honor” or a rite of passage.

PATIENT PRESENTATION

- Anterior auricular tenderness
- Rapid onset of swelling and deformity of the auricle
- Erythema or purplish hue to the damaged portion of the auricle

Careful exam of the scalp, face, external auditory canal, and tympanic membranes is required to look for more significant, and potentially life-threatening injuries, such as a basilar skull fracture or traumatic brain injury, requiring more urgent treatment. Involvement of other specialists, such as a trauma surgeon or neurosurgeon, may be warranted. Early consultation with ear/nose/throat (ENT) colleagues for more significant injuries should be considered early in the patient’s presentation as well.

TREATMENT

Because there are currently no evidence-based guidelines for the best way to treat auricular hematomas, consideration of the patient’s activity, their need to get back to that activity, willingness to comply with treatment, ability to follow up, and concern for cosmetic outcomes need to be considered with the patient when selecting a method of treatment. All methods of treatment involve complete evacuation of the hematoma by either aspiration or incision and drainage. Aspiration is typically most effective for smaller hematomas and those that present soon after occurrence. Some sort of compression is also frequently recommended after evacuation to prevent reaccumulation of the hematoma. No one method has proven superior to prevent reoccurrence, and numerous ways have been suggested for preventing hematoma reaccumulation. For the athlete anxious to get back to training and competition, who does not or will not comply with treatment, bolstering, incision, and drainage followed by absorbable mattress suture repair should be considered. Another option is aspiration of the hematoma and compression of the hematoma using specifically designed magnets, which can be moved, cleaned, and allow for easy reexam for reaccumulation and further aspiration if required. Both methods allow patients to return to training and competition much sooner, so patients tend to better comply with this treatment.

The classic way to provide compression following drainage is to use some sort of bolster sutured to each side of the ear. Although numerous methods for bolstering have been described, cotton dental rolls, petroleum gauze, or pieces of suction catheter tips seem to be the most common methods of bolstering used outside of specialty care as these materials are readily available. This method provides effective treatment, but may increase the likelihood of infection. Antibiotic prophylaxis against skin flora, such as *Staphylococcus* and *Streptococcus*, is generally recommended, especially if bolsters are in place. Further prophylaxis with antipseudomonal drugs is recommended with cartilage exposure or for patients who are immunocompromised.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Hematoma greater than 7 to 10 days old
- Recurrent or chronic hematoma

These types of injuries should get ENT referral due to the likelihood that the fibrotic neocartilage is already forming and caused the more permanent deformity. Additionally, wounds with skin or cartilage loss likely require ENT consultation for more extensive and complicated repair.

SPECIAL CONSIDERATIONS

- Procedural sedation may be necessary for pediatric or anxious patients to prevent excessive movement.
- Immunocompromised patients or those who have comorbidities should receive prophylactic antibiotics covering *staphylococcus*, *streptococcus*, and *pseudomonas*.
- Police and protective services should be contacted for any concerns for abuse.

PROCEDURE PREPARATION

Prior to performing any of the following procedures, gloves and personal protective gear, including eye shield, should be worn. Material for bolsters and compression dressing should also be prepared prior to hematoma evacuation.

Needle Aspiration

- Alcohol wipe to clean injection site
- 18- to 20-gauge needle
- 10-mL syringe
- Topical antibiotic ointment

Incision and Drainage

- Betadine or Hibiclens to clean skin and sterile drapes
- 3-mL syringe with 23- to 27-gauge needle—anesthesia
- Lidocaine 1% *without* epinephrine for anesthesia
- No. 11 or No. 15 blade scalpel
- 20-mL syringe with 18-gauge angiocath and normal saline for irrigation
- Suction with Frazier suction tip
- Curved hemostats to break up any loculations or to remove any clotted blood
- Topical antibiotic ointment

Compression Dressing

- 4 × 4 gauze pads
- Stretch bandage/roll gauze
- Dry cotton
- Petroleum gauze, or saline-soaked gauze

Sutured Bolsters

- Dental rolls, or cut pieces of 14- or 16-gauge suction catheter tips corresponding to the size of the hematoma
- 4-0 nylon suture material
- Suture kit

PROCEDURE

Small Hematoma

NEEDLE ASPIRATION

- Prepare the site with skin cleanser and dry with a piece of 4 × 4 gauze.
- Attach the 18- to 20-gauge needle to the 10-mL syringe.
- Insert the needle into the hematoma (**FIGURE 44.1**).
- "Milk" the hematoma between your thumb and forefinger until the contents are completely drained.
- Withdraw the needle from the ear.
- Apply a simple compression dressing to the ear to prevent reaccumulation (**see FIGURE 44.3**).

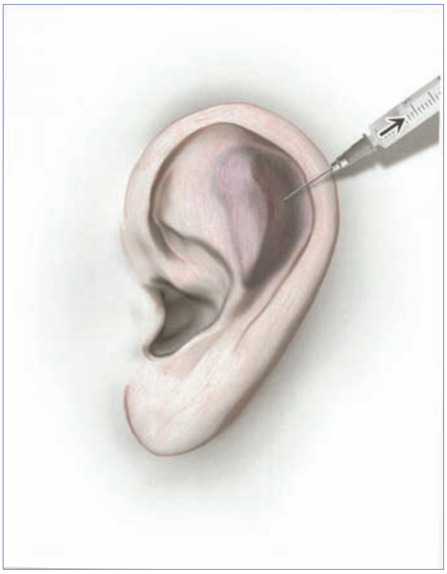

FIGURE 44.1 Needle aspiration of an auricular hematoma.

Incision and Drainage

- Place the patient in the lateral decubitus position with the affected ear facing upward.
- Prepare the area with skin cleanser and dry with a 4 × 4 gauze pad.
- Perform local infiltration with the lidocaine 1% *without* epinephrine (an auricular block can also be performed; see Chapter 20, Procedures for Performing Auricular Anesthesia).
- After anesthesia, prep and drape the ear in a sterile manner. Gown and sterile gloves should be worn for the remainder of the procedure.
- Using the scalpel, incise along the natural skin fold of the anterior auricle following the curve of the pinna (**FIGURE 44.2**).
- Gently peel the skin and perichondrium off the hematoma.
- Completely evacuate the hematoma (suction may be used if necessary).
- Draw the saline into the large syringe.
- Apply the splash shield to the end of the syringe.
- Irrigate the area.
- Dry thoroughly.
- Apply topical antibiotic ointment liberally and approximate the wound edges.
- Apply a pressure dressing (**see FIGURE 44.3**) or suture bolsters to the ear (**see FIGURE 44.4**).

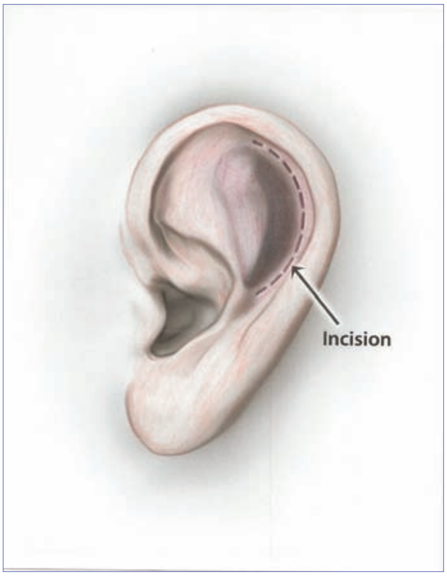

FIGURE 44.2 Incision and drainage of an auricular hematoma.

Compression Dressing

- Insert dry cotton into the ear canal.
- Mold the conforming gauze (petroleum- or saline-soaked gauze) into the convolutions of the ear.
- Cut a "V" shape into the 4 × 4 gauze pads to allow for a snug and comfortable fit behind the ear. Place them behind the entire ear. Use three to four 4 × 4 gauze pads to provide adequate packing.
- Place multiple layers of gauze over the ear.
- Wrap the stretch bandage/roll gauze around the head to secure the dressing in place (**FIGURE 44.3**).
- Do not cover the unaffected ear in the bandage.

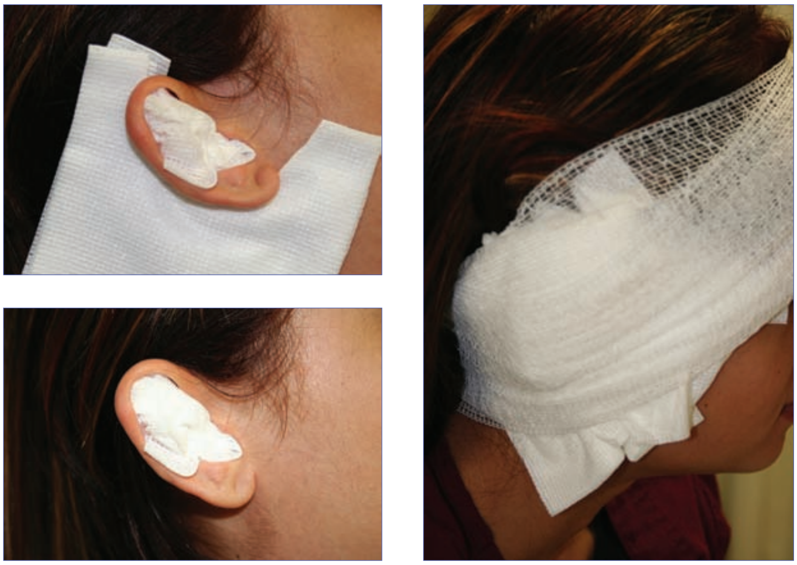

FIGURE 44.3 Application of compression dressings.

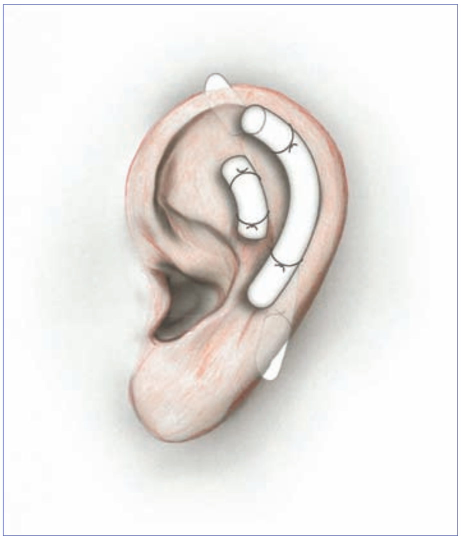

FIGURE 44.4 Illustration depicting suture dental rolls.

Sutured Dental Rolls

- Pieces cut from 14-gauge or 16-gauge suction catheter tips may also be used for bolstering instead of dental rolls or petroleum gauze, allowing earlier identification of hematoma reformation because they are clear. Either can provide the necessary compression.
- Place catheter piece or roll on both anterior and posterior sides of auricle.
- Insert 4-0 nylon suture material from anterior side of ear through the entire thickness of the auricle, coming out on the posterior side of the ear.
- Pass the suture back through the posterior side of the auricle to the anterior side of the auricle, looping the posterior bolster with the suture.
- Tie the suture in place on top of the anterior bolster using at least five to seven knots.
- Repeat this process on the opposite end of the bolster to secure the bolster in place (**FIGURE 44.4**).
- Remove the dressing in 5 to 7 days.
- The patient should have ENT follow-up in 24 hours to assess for reaccumulation of the hematoma, infection, or vascular compromise.

POSTPROCEDURE CONSIDERATIONS

- Drainage may need to be repeated if fluid reaccumulation occurs.
- Referral to an ENT specialist is indicated.

EDUCATIONAL POINTS

- Close follow-up every 24 hours is necessary to assess for recurrence, infection, and vascular compromise.
- Aspirin, nonsteroidal anti-inflammatory medication, or anticoagulant medications should be avoided to help prevent recurrence.
- The patient should not participate in any further contact sports until cleared to do so by ENT to minimize the risk of reaccumulation of the hematoma, regardless of the treatment method.
- Patients should be instructed to inspect the wound frequently and to return for signs of reaccumulation, vascular compromise, or infection.

COMPLICATIONS

- Reaccumulation of the hematoma is the most common complication seen.
- Infection, chondritis, and cosmetic deformity may also occur.

- Early drainage and close monitoring can help prevent the development of scar tissue (cauliflower ear). However, it may still develop, and this needs to be stressed to patients and their families.
- Recurrence and infection are indications for surgical treatment and intravenous antibiotics.

PEARLS

- Discuss the possibility of reoccurrence and development of cauliflower ear with the patient.
- Premedicate with oral analgesic medication, and use procedural sedation if required.
- ENT consultation is essential, even if it is just to ensure close follow-up.
- Drainage should be performed on all hematomas presenting within 7 days of injury.
- The use of lidocaine with epinephrine has generally been contraindicated for the outer ear. However, recent literature suggests that the use of epinephrine does not block the circulation to this area of the ear and, therefore, does not cause necrosis. The decision to use epinephrine for local infiltration of the outer ear is at the clinician's discretion and should be based on the most up-to-date evidence. Epinephrine is also acceptable for regional block of the ear.

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UNIT

XIII

Procedures for Examination and Management of Common Oral Injuries

CHAPTER 45

Dental Anatomy, Examination, and Anesthetics

Melanie Gibbons Hallman and Theresa M. Campo

BACKGROUND/DENTAL ANATOMY

Familiarity with the anatomy and development of teeth and the succession of tooth eruption are key elements for accurate diagnosis and treatment of dental injuries and infections. Tooth structure consists of the crown (visible part of the tooth above the gingiva), and one or two roots depending on the location of the tooth in the mouth. Bone and periodontium enclose roots. When viewed cross-sectionally, the tooth consists of three layers:

- Surface enamel – a very dense, rigid ectodermal material that covers and protects the crown. It has minimal collagen content and is the hardest substance in the body. Enamel is translucent giving way to the color of the dentin.
- Dentin – the middle layer and most abundant portion of the tooth within the crown and root is a specialized connective tissue like bone and cementum. Both dentin and enamel are composed of hydroxyapatite but dentin has higher organic content composed mostly of collagen making it more flexible than enamel and giving teeth the ability to absorb force without fracturing.
- Pulp – the inner core containing nerves, arteries, and veins that supply the dentin with nutrients.

Note that dentin is harder than bones yet not as hard as enamel. Also, enamel does not regenerate if disrupted. Roots are connected to periodontal ligaments that attach each tooth to a socket of alveolar bone located within the mandible and maxilla. The root system is also composed of three layers: the cementum (outer layer), dentin (middle layer), and the pulp canal (the center). **FIGURE 45.1** illustrates the anatomy of a tooth.

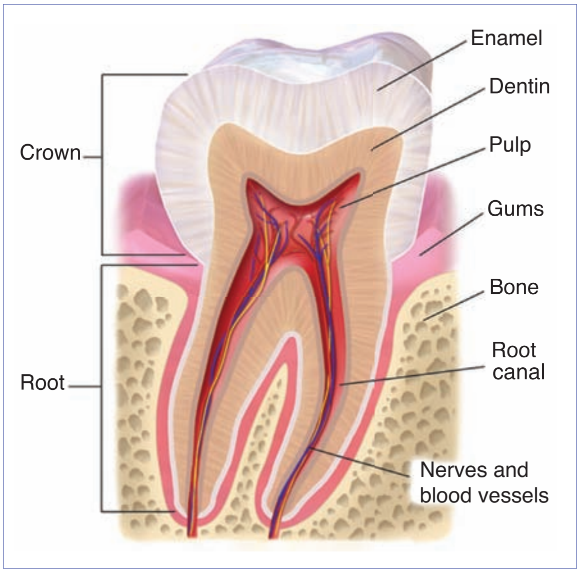


FIGURE 45.1 Tooth anatomy.

The teeth affect speech and facial contour, and provide the ability to pierce, tear, and grind food. Teeth evolve in two phases, producing primary and secondary teeth with a shedding phase between. Primary tooth eruption begins around 6 months of age, usually starting with the lower central incisors and continuing to the last molars by age 3; these are typically shed by age 18. There are 20 primary teeth, which are identified by letters A through T, going from the patient's right to left on top, then left to right on the bottom.

Secondary teeth, or adult permanent teeth, consist of 32 teeth: eight incisors, four canines, eight premolars, and 12 molars. Permanent tooth eruption begins around age 6 and continues until late adolescence. Permanent teeth are numbered from the patient's right to left on top, then left to right on bottom and are numbered 1 through 32 (**FIGURE 45.2**). Permanent teeth may include erupted wisdom teeth; however, due to space constraints, these teeth often fail to erupt and are removed to allow room for remaining teeth to function.

The teeth can be divided into two areas: the upper and lower arches (maxillary and mandibular teeth). These areas can be further divided into the four areas of upper and lower, right and left. They are referenced to the patient (i.e., patient's right upper or left lower). There are four groups of teeth: the incisors, canines, premolars, and molars.

Incisors

- The four most anterior maxillary and four mandibular teeth
- Responsible for cutting and biting food
- Have one root each

Canines

- Two maxillary, two mandibular
- Distal to the incisors
- Responsible for ripping and tearing food
- Are the longest and most stable teeth
- Have one root each

Premolars

- Four in both the maxilla and mandible
- Sharp points and a broad base used for ripping, chewing, and grinding food
- Have one root, but the first maxillary may have two roots

Molars

- Are the farthest back; six in both the maxilla and mandible
- Broad surface for crushing, chewing, and grinding food
- May have one to four roots
- The third molars in both the maxilla and mandible are called *wisdom teeth*.

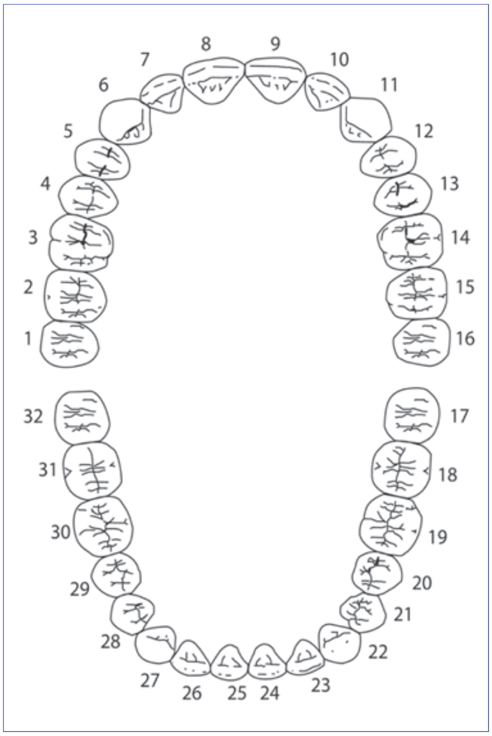


FIGURE 45.2 Universal numbering system of adult teeth.

DENTAL EXAMINATION

A thorough dental assessment should be conducted before administering treatment. Close examination of the oral cavity should be completed for complaints of facial swelling, sore throat, sinus pressure, neck or oral pain, swelling, or drainage. Because of the close anatomical relationship of these juxtaposed structures and the plethora of fascial divisions, these areas should be examined closely as well in regards to the potential contiguous spread of pathology/infection. Prior to beginning the examination, the patient should remove any dentures or removable appliances for full visualization. An examination of the entire head, neck, and mouth should be completed. The mechanism of injury is crucial when assessing dental trauma history. Injuries to teeth associated with significant force are often associated with head and neck trauma. Child maltreatment should be considered when children sustain significant dental injury without a credible mechanism. Any active bleeding should be controlled. Medical and traumatic injuries override dental injuries and should be stabilized before dental assessment and care are provided. Any suspected abuse or neglect is reportable by law.

Inspection

- External features of the face and neck
- Jaw movement for symmetry—malocclusion
- Lips for swelling, lesions
- Phonation
- Swallowing

Intraoral

- Mucosa and tissue, including frenula
- Torn frenulum can be a sign of abuse

Moisture of Tissues

GINGIVA

- Inflammation could be a sign of systemic disease (i.e., diabetes) or pregnancy
- Color (erythema, pallor, cyanosis, darkening)

TEETH

- Identify affected teeth using 1 to 32 numbering system for permanent teeth, letters A to T for primary teeth.
- Discoloration can occur because of medications, poor hygiene, and injury.
  - Antibiotics
    - Tetracycline/Doxycycline/Minocycline
      - Affects enamel formation in children under the age of 8
      - Nursing mothers or expectant mothers should avoid these in the last half of pregnancy as it can affect the future appearance of babies' teeth
    - Tigercycline
    - Augmentin
    - Clarithromycin/Erythromycin
    - Chlorhexidine
      - Found in some mouth rinses
    - Ciprofloxacin
    - Zyvox
  - Antihistamines
  - Antipsychotics
  - Elements
    - Fluoride
    - Iron
  - Antihypertensives
    - Many classes can lead to dry mouth/tooth decay
- Check for any movement.
- Note temperature sensitivity.
- Note missing teeth, fractures, damage to integrity of teeth.

TONGUE

- Inspect for lesions, cuts, bleeding, and swelling.

HARD AND SOFT PALATE

- Note lesions.
- Have patient say "ahhh" and note symmetrical rise of uvula/palate.
- Note swelling.

PALPATION

- Periauricular, submandibular, submental, and cervical lymph nodes
- Temporomandibular joint
- Check symmetry of movement
- Note clicking or crepitus
- Intraoral tissue, including the frenula
- Gingiva
- Teeth for mobility and tenderness
- Note chipping, breakage, roughness, and mobility
- Express Wharton's duct located under tongue (fluid should be clear)
- Hard and soft palate
- Note masses

ANESTHETICS

BACKGROUND

Dental anesthesia is used for many dental, oral, and maxillofacial procedures, including odontalgia (toothache) and lacerations. Dental blocks do not distort soft tissue needing repair and are a safe way to control pain without the use of narcotics.

Profound anesthesia can be achieved through infiltration, or depositing anesthetic apically to a particular tooth. This can be accomplished for all teeth in the mouth with the exception of the lower molars. The lower molars usually require a mandibular block (inferior alveolar infiltration/lingual nerve). Infiltration typically provides profound anesthesia to the pulp in approximately 4 minutes and can last about 7 minutes, with soft tissue numbness lasting 2 to 3 hours. The mandibular block can take up to 15 minutes to achieve profound anesthesia and can last 4 to 5 hours or longer depending on the anesthetic used.

TREATMENT

Indications for dental anesthesia may include the following:

- Odontalgia and pulpitis
- Dental impaction
- Periodontal abscess
- Laceration repair of the tongue, lip, and oral mucosa
- Dental, mandibular, and/or maxillary fractures and trauma

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Hypersensitivity or allergies to anesthetic agents
- Uncooperative patients
- Infected tissue
- Bleeding disorders
- Valvular heart disease

SPECIAL CONSIDERATIONS

- Be cognizant of organ dysfunction (e.g., liver), which can increase the half-life of lidocaine twofold, as well as stress ailing pathology; always consult product information (in general, local anesthetics are quite safe).
- Have proper documentation of a patient with a history of neurovascular damage.

PROCEDURE PREPARATION

- Lidocaine 5% or benzocaine 20% solution for topical application
- Nonsterile gloves

- Absorbent pads
- Gauze
- Cotton-tipped applicator(s) or cotton balls
- Lidocaine 1% or 2% or bupivacaine 0.25% with or without epinephrine
- Dental aspirating syringe, if available
- 3-mL syringe with 1.5-inch needle
- Small-gauge needle (25- to 27-gauge)
- Suction setup with Yankauer suction tip

PROCEDURE

Topical

Application of topical anesthesia can be beneficial in reducing the pain experienced with injectable anesthesia.

- Dry mucosa with gauze.
- Place lidocaine 5% or benzocaine 20% solution on the tip of applicators or cotton balls.
- Where needle is to be inserted, place on mucosa for 3 to 5 minutes (**FIGURE 45.3**).

Injectable

Injectable anesthesia can be used for laceration repair, mandibular fractures, toothache, and abscess. Lidocaine 1% or 2% with or without epinephrine can be used for lacerations (short term) or bupivacaine 0.25% with or without epinephrine can be used for mandibular fractures or toothaches (long term) for their respective durations.

Supraperiosteal Infiltration (Local)

- Used for individual tooth pain of:
  - Maxillary incisors
  - Canines
  - Premolars
- Apply topical anesthetic for 3 to 5 minutes (see topical anesthesia procedure).
- Have patient close mouth to relax facial muscles.
- Expose and grip the mucous membrane with gauze.
  - Pull gently out and down (mandible).
  - Pull gently out and up (maxilla).
- Visualize the mucobuccal fold.

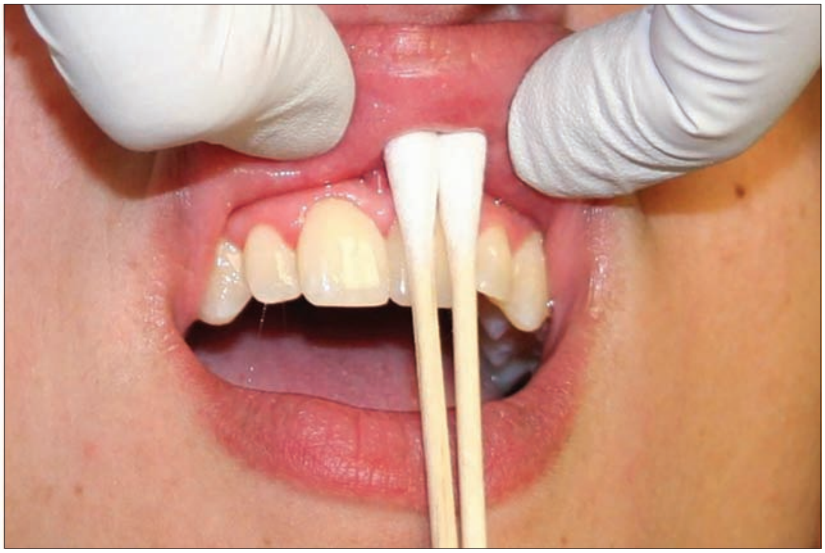
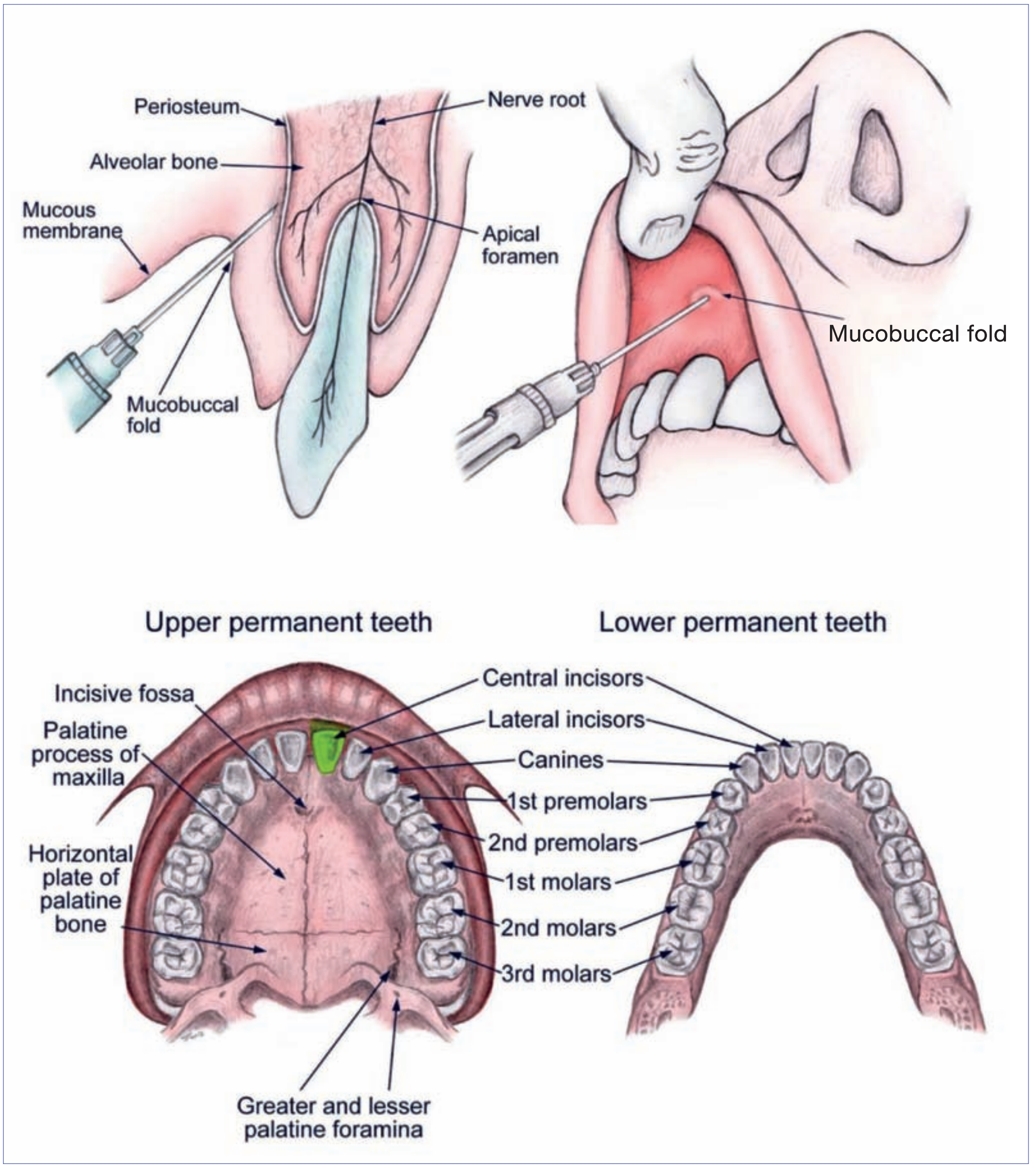


FIGURE 45.3 Application of topical anesthesia.

- Insert the needle into the mucous fold, in front of the affected tooth, with the bevel of the needle facing the bone and aimed toward the mandible or maxilla (**FIGURE 45.4**).
- Contact the bone with the needle and pull back approximately 1 mm.
- Aspirate.
- Inject 1 to 2 mL of anesthetic at the apex of the tooth.
- Withdraw the needle.
- Give patient gauze to hold pressure.
- If the procedure fails to anesthetize the area, inject the palatal side of the tooth.

Anterior Superior Alveolar Block

- Maxillary canines
- Central and lateral incisors
- Mucosa above these teeth
- May extend to contralateral incisors



Periosteum
Nerve root
Alveolar bone
Mucous membrane
Apical foramen
Mucobuccal fold
Mucobuccal fold
Upper permanent teeth
Lower permanent teeth
Incisive fossa
Palatine process of maxilla
Horizontal plate of palatine bone
Central incisors
Lateral incisors
Canines
1st premolars
2nd premolars
1st molars
2nd molars
3rd molars
Greater and lesser palatine foramina

FIGURE 45.4 Supraperiosteal infiltration.

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- Visualize the intersection of the mucobuccal fold and apex of the canine tooth.
- Apply topical anesthetic for 3 to 5 minutes (see topical anesthesia procedure described earlier).
- Retract the lip anteriorly.
- Insert needle at the apex of the canine tooth at a 45-degree angle (**FIGURE 45.5**).
- Advance the needle approximately 1 to 1.5 cm.
- Aspirate.
- Inject 2 mL of anesthetic.
- Withdraw the needle.
- Massage injection site 20 seconds.
- Give patient gauze to hold pressure.

Middle Superior Alveolar Block

- Maxillary premolars
- May overlap to canine and first molar
- Locate intersection of mucobuccal fold and juncture of maxillary premolar 2 / molar 1.

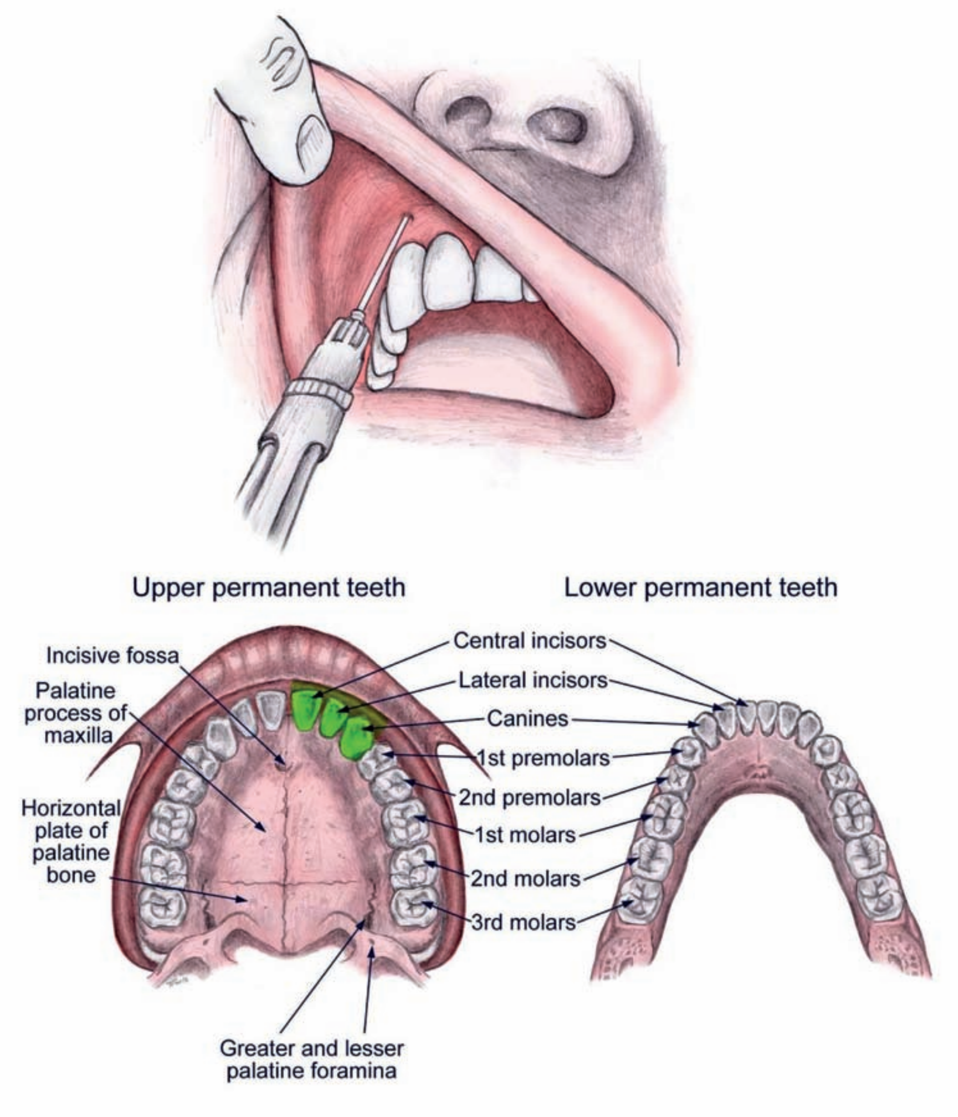
Upper permanent teeth
Lower permanent teeth
Incisive fossa
Palatine process of maxilla
Horizontal plate of palatine bone
Central incisors
Lateral incisors
Canines
1st premolars
2nd premolars
1st molars
2nd molars
3rd molars
Greater and lesser palatine foramina

FIGURE 45.5 ASA block.

ASA, anterior superior alveolar.

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- Apply topical anesthetic for 3 to 5 minutes (see topical anesthesia procedure described earlier).
- Have the patient open their mouth about halfway.
- Retract the cheek laterally.
- Insert needle at the intersection previously described at a 45-degree angle (**FIGURE 45.6**).
- Advance needle 1 to 1.5 cm.
- Aspirate.
- Inject 2 to 3 mL local anesthetic.
- Withdraw needle and massage site for 20 seconds.

Posterior Superior Alveolar Block

MAXILLARY MOLARS

- Have the patient open the mouth about halfway with jaw pushed toward the clinician.
- Retract the cheek laterally.
- Visualize intersection of the mucobuccal fold and interface of molars 1 and 2.
- Apply topical anesthetic for 3 to 5 minutes (see topical anesthesia procedure described earlier).

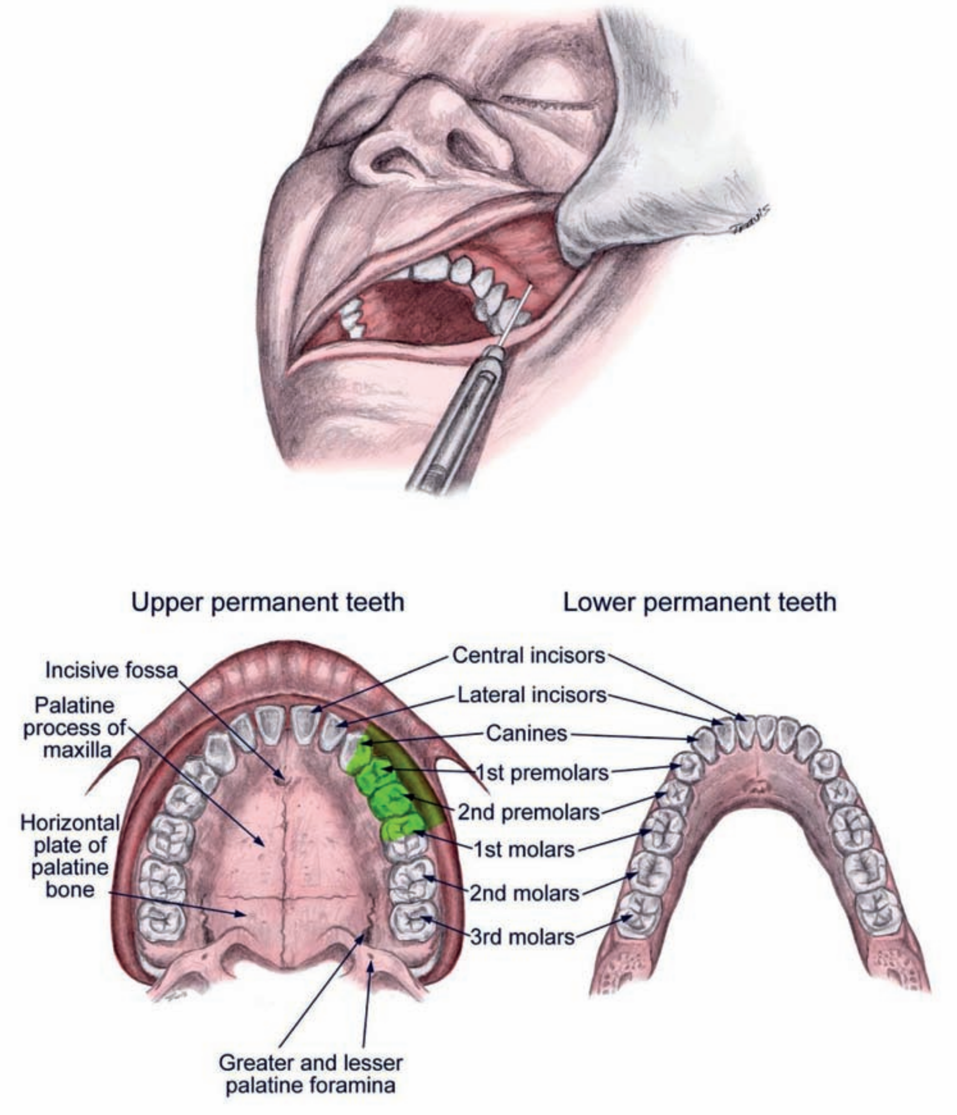
Upper permanent teeth
Lower permanent teeth
Incisive fossa
Palatine process of maxilla
Horizontal plate of palatine bone
Central incisors
Lateral incisors
Canines
1st premolars
2nd premolars
1st molars
2nd molars
3rd molars
Greater and lesser palatine foramina

FIGURE 45.6 Middle superior alveolar block.

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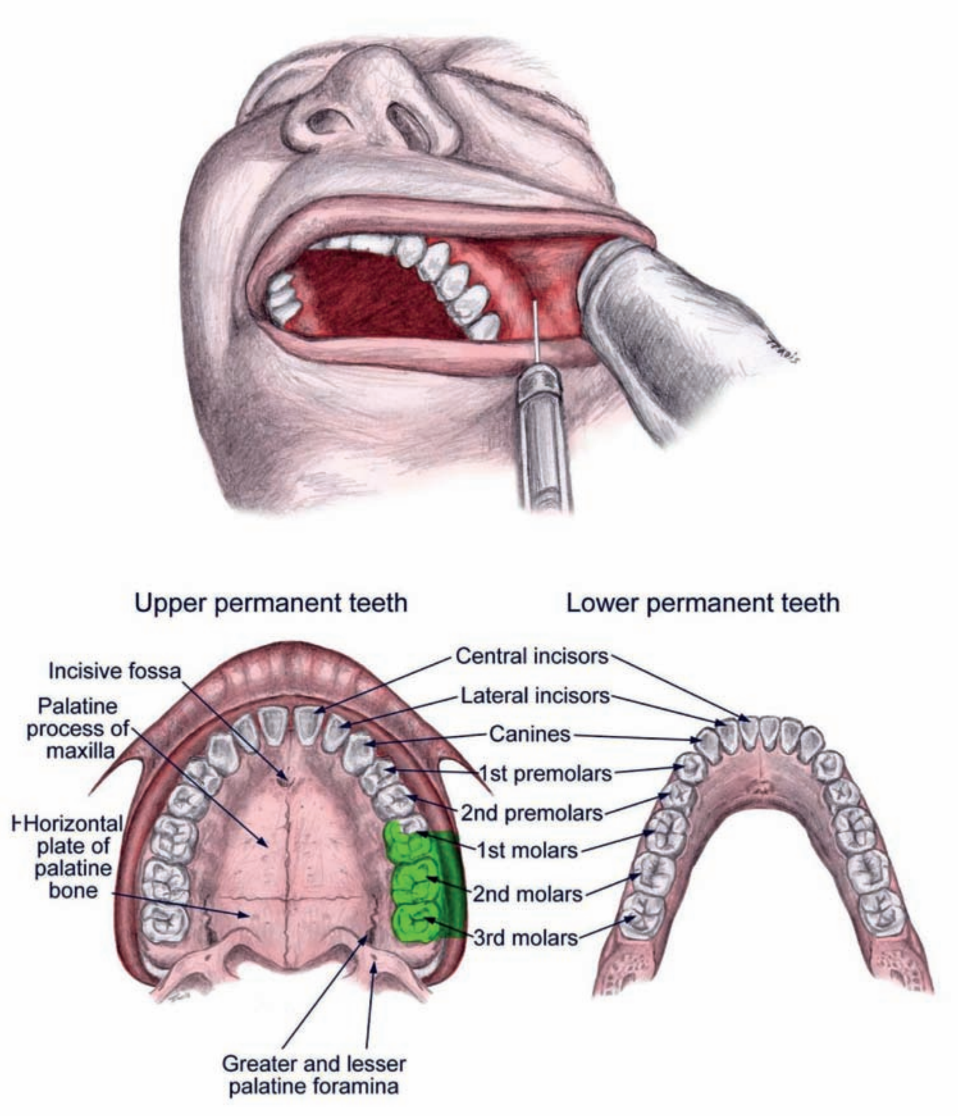
- Position the needle to the posterior aspect of the second molar and insert toward the maxillary tuberosity, (upward, backward, and inward) along the curvature of the tuberosity, approximately 2 to 2.5 cm (**FIGURE 45.7**).
- If needle impacts bone, withdraw and insert more laterally.
- Aspirate.
- Inject 2 to 3 mL of anesthetic.
- Withdraw the needle and massage injection site for 20 seconds.
- Give patient gauze to hold pressure.
- Occasionally, the first molar will not be anesthetized with this technique alone and will need an additional technique (middle superior alveolar [MSA] or supraperiosteal block).
- Puncture of the pterygoid plexus and hematoma formation can occur if aspiration is not performed.
- Cranial nerve V can be blocked if the needle is inserted too far posteriorly.

Upper molars and upper first premolars may require a palatal injection because these teeth possess a palatal root. Determine approximately where the root tip would be in the palate and, using a blunt object (such as the blunt end of the dental mirror), apply gentle pressure. At the same time, insert the needle into the tissue near the mirror handle. Slowly express a small amount of anesthetic into the site. Use only a small amount (few drops); tissue blanching is a good indication enough anesthetic has been applied. Application of too much anesthetic with pressure applied can result in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Central incisors
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1st premolars
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3rd molars
Greater and lesser palatine foramina

FIGURE 45.7 Posterior superior alveolar block.

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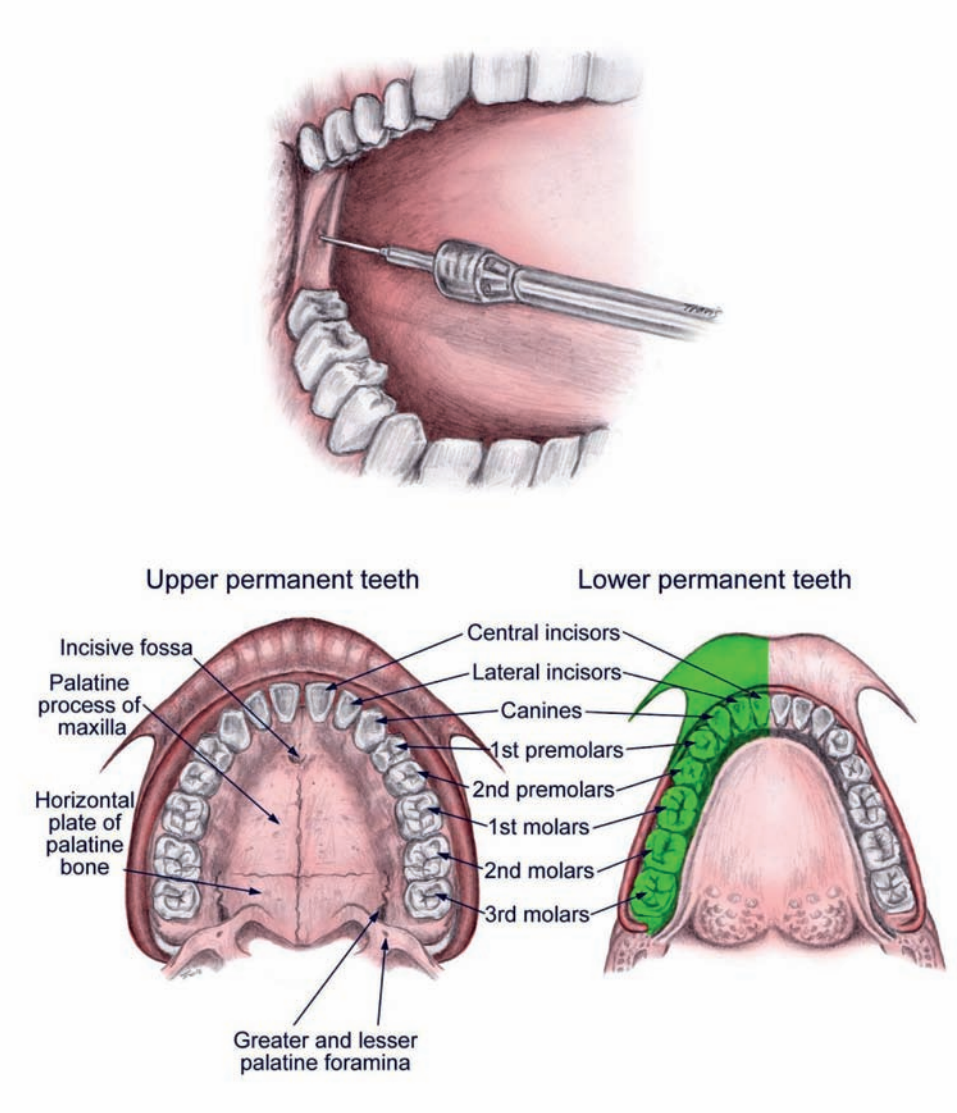
necrosis. This procedure is well tolerated because of the gate theory of pain, which states that the larger pressure nerve fibers will override the smaller pain nerve fibers. This is why rubbing your head after you hit it is soothing.

Inferior Alveolar Infiltration (With Lingual Nerve Block)

- This is the most common type of dental nerve block.
- It is used to anesthetize the mandibular teeth to midline, the floor of the mouth, lower lip, chin, and anterior two-thirds of the tongue.
- This is a highly effective block, administration of which should be performed only after reading and reviewing procedural resources and with supervision until one is proficient in this technique.
- Have the patient sit reclined on the stretcher with the head firmly against the stretcher, tilted slightly toward the clinician.
- Stand on the side opposite the area to be injected.
- Palpate the coronoid notch and then place the thumb over the notch (retromolar fossa—anterior ramus of the mandible).
- Place the index finger just anterior to the ear (external ramus).
- Retract the tissue toward the cheek and visualize the pterygomandicular triangle (**FIGURE 45.8**).


Upper permanent teeth
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Greater and lesser palatine foramina

FIGURE 45.8 Inferior alveolar block.

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- For the lingual nerve block, realize that the teeth will not be anesthetized, so best used for a tongue laceration (**FIGURE 45.9**); in the authors' opinion, the inferior alveolar nerve block is a simpler method for anesthetizing the lingual nerve.
- Apply topical anesthetic for 3 to 5 minutes (see topical anesthesia procedure described earlier).
- Hold the syringe parallel to the mandibular teeth at an angle to the medial ramus with the distal end of the syringe lying between the first and second premolars on the opposite side of the mouth.
- In children, the syringe will need to be held at a slightly higher angle, not parallel, because of the difference in anatomy (mandibular foramen is lower).
- Insert the needle into the triangle approximately 1 cm above the level of the teeth until the end of the needle hits the bone (usually no more than 2.5 cm).
- Withdraw the needle slightly, aspirate, and then instill the anesthetic.
- 5 mL
- The lingual nerve will inadvertently be anesthetized as well secondary to its branching off of the inferior alveolar nerve (**FIGURE 45.9**).
- Patients may experience jaw soreness after the injection for a few days. Be sure to include this information in your instructions.

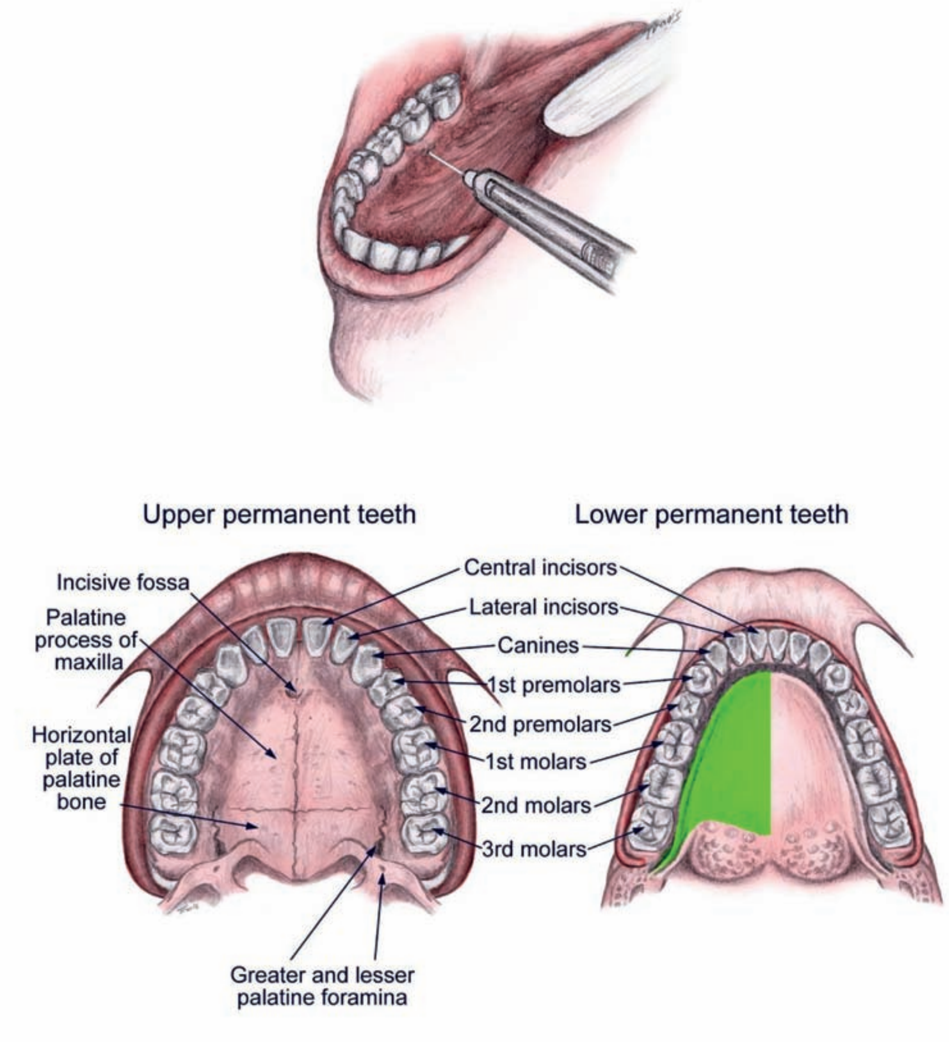
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FIGURE 45.9 Lingual nerve block.

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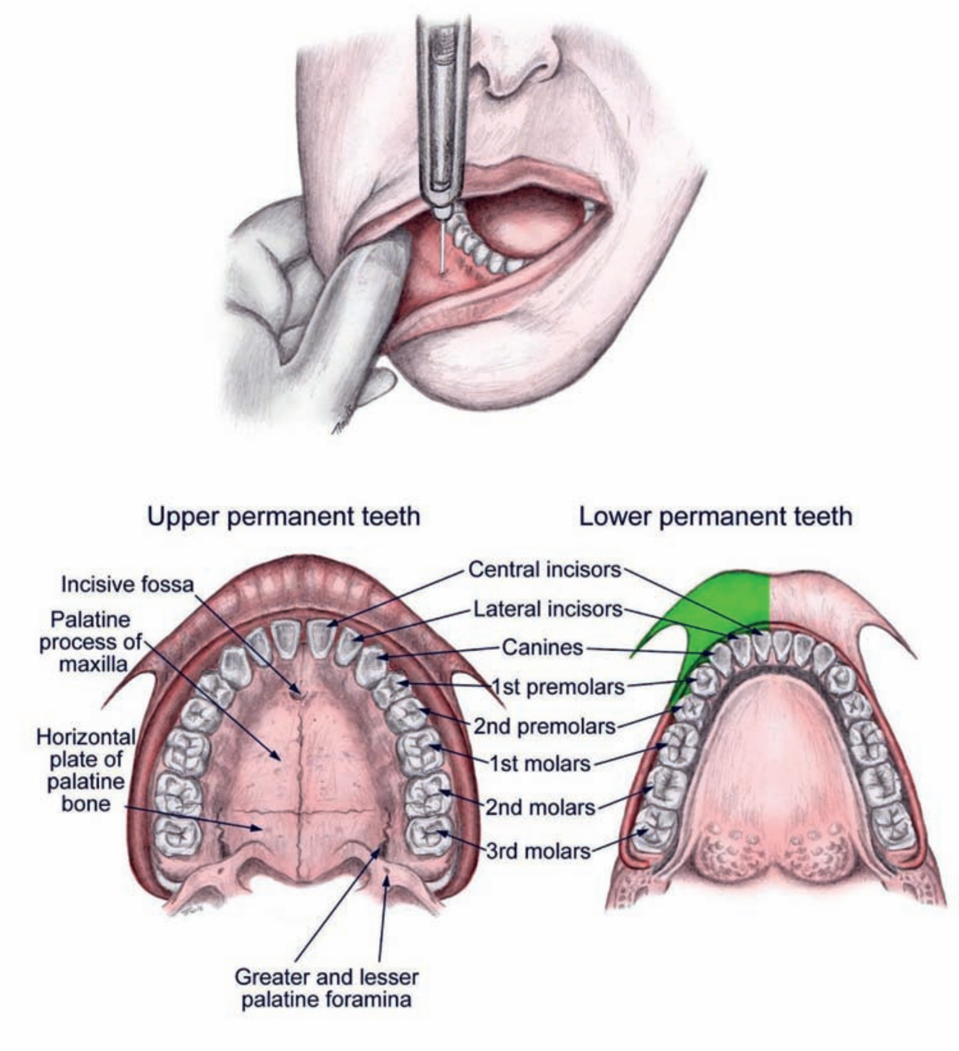
Mental Nerve Infiltration

- This is most commonly used for lower lip lacerations.
- It is not used for teeth.
- The mental nerve is an extension of the inferior alveolar nerve through the mental foramen.
- This nerve block can be performed either intraorally or extraorally. However, only the intraoral technique is covered in this book as it is considered to be less painful to the patient.
- Palpate the mental foramen by retracting the cheek and lip. Locate junction of mandibular premolars 1 and 2 and downward 1 cm inferior to gum line (just medial to midline pupil) over the labial fold.
- Apply topical anesthetic for 3 to 5 minutes (see topical anesthesia procedure described earlier).
- Insert needle 1 cm inferior to second premolar at 45-degree angle (see **FIGURE 45.10**).
- Advance needle until it contacts bone of mandible and withdraw slightly.
- Aspirate.
- Inject 2 to 3 mL anesthetic following a fan pattern.
- Withdraw needle and massage site for 20 seconds.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3rd molars
Greater and lesser palatine foramina

FIGURE 45.10 Mental nerve block.

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EDUCATIONAL POINTS

- Rinse with warm salt water.
- Use caution chewing and swallowing food and fluids after administration of a dental block related to numbing effects of anesthesia and the potential for temporary decrease in gag reflex.
- Avoid use of straws for post procedure drinking.

COMPLICATIONS

- Pain
- Infection
- Allergic reaction
- Anxiety

PEARLS

- Always obtain informed consent before providing dental procedures.
- Distraction through imagery can help to decrease the patient's anxiety.
- An apprehensive patient or a patient with pulp infection may require additional anesthetic.
- Having a parent or significant other at the bedside may comfort patients during dental procedures.
- Massaging the injection site can help increase the speed of absorption and distract from pain.
- Injecting slowly over 30 seconds to 1 minute may decrease pain caused by administration of anesthetics.
- Make sure the periosteum of the dental bone is encountered when performing inferior alveolar nerve anesthesia.
- At minimum, use a 25-gauge needle for nerve blocks and aspiration.
- More than one attempt to achieve a nerve block may be necessary.

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CHAPTER

46

Procedures for Managing Dental Injuries

Melanie Gibbons Hallman

Dental pain and injuries are commonly seen in emergency and urgent care settings and less frequently in the office setting. They can be anxiety producing for both the patient and family members. Dentoalveolar abscesses, odontalgia (toothache), dental fractures, and luxations are the most common problems requiring quick intervention. Other problems encountered by providers are pulpitis, gingivitis, pericoronitis, cellulitis, and periodontitis, and are not covered in this chapter.

Oral injuries are most common up to age 10 and decrease gradually until around age 30. They become rarer after age 30. Oral injuries account for 5% of all bodily injuries. Dental injuries account for 92% of all oral injuries. Dental luxations and crown fractures are the most common types of dental injuries. Young males sustain dental injury more frequently than young females. This may be accounted for in part by more involvement in contact sports in males. Dental injuries require considerable time to treat and are often very costly. Prognosis is dependent on early, rapid, and correct treatment. Dental treatment in emergency services is often inadequate, and accessing current guidelines for these services and procedures is of utmost importance to improve outcomes and patient satisfaction with results. According to the trauma guidelines of the International Association of Dental Traumatology (2012), stabilizing the injury, eliminating or minimizing complications from bacterial infection, promoting healing by reimplanting and correctly repositioning teeth, and preserving alveolar ridges in children using best evidence for urgent treatment of dental injuries provide the best success.

Direct costs coupled with the indirect costs of days lost at school and work are not only a financial burden on the individual and family, but also on society. Providers can address these problems early and efficiently through procedures, medical treatment, and referral to dentists and oral surgeons.

DENTOALVEOLAR ABSCESS

BACKGROUND

Dentoalveolar abscesses occur when enamel breakdown forms a pit that increases in size allowing plaque and debris to collect, leading to development of an abscess (collection of pus) involving the pulp space of the tooth. Predisposition to acute dental abscesses is caused by underlying poor dentition or dental caries, periodontitis (chronic infection of supporting tooth structures), pericoronitis (partially erupted teeth), and trauma. Elderly people, persons with poorly controlled diabetes, and other immunocompromised patients are subject to dental infections. Patients with reduced socioeconomic resources are at disproportionate risk for dental infections due mostly to poor access to dental care. A periodontal abscess is more common in adults and involves the periodontal ligaments and bone (support structures). When seen in children, periodontal abscesses usually result from foreign bodies. Periapical abscesses are the most common type of dental abscess seen in children. Left untreated, periapical abscesses can result in necrosis of dental pulp. Abscess of anterior teeth is uncommon in all ages. Lower posterior teeth are the most often affected, with the third lower molar being the most frequently affected dental site. Tooth decay or injury does not have to be present for an abscess to develop. If infection is significant, trismus, dysphagia, dehydration, edema

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

of the neck and face, and respiratory compromise may be present. Streptococcal serotypes are responsible for most oral infections. Removal of the infection and underlying cause of infection and prescribing a correct antibiotic are usually successful in managing most dental abscesses. **FIGURE 46.1** show a dentoalveolar abscess.

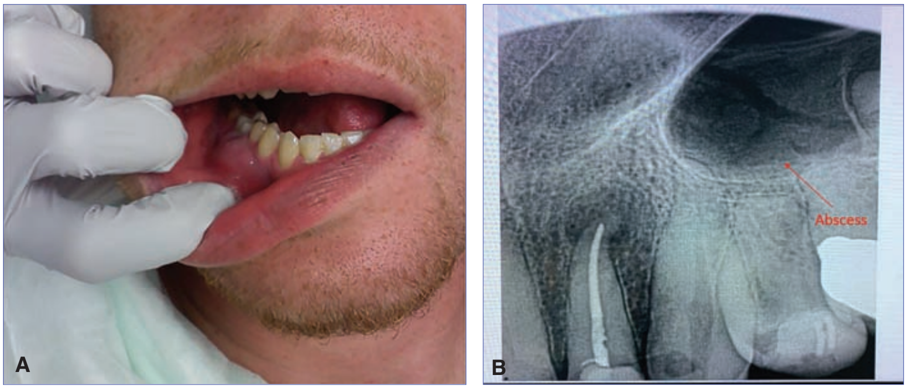

FIGURE 46.1 (A) Photograph and (B) x-ray of dentoalveolar abscess.

Source: (B) Courtesy of Dr. Craig Stafford.

PATIENT PRESENTATION

- Toothache (may radiate to other structures, i.e., ear on the same side)
- Localized pain (buccal and/or facial; along facial plains); please see **TABLE 46.1**
- Evolving erythema
- Palpable dentoalveolar ridge swelling and warmth of gingival tissue (develops over hours to days and may involve extraoral tissues)
- Feeling of increased pressure in the involved tooth
- Increased sensitivity to heat, cold, and air
- Tenderness to percussion of the involved tooth, discomfort when pressure is applied to the involved gum (periapical abscess)
- Gingival bleeding or spontaneous drainage of pus may be present with periodontal abscess
- A single erythemic papule may be present on the buccal side of the gum in chronic abscesses; the papule may be soft or fluctuant and is usually located facial and apical to the abscessed tooth
- Mobility of tooth/teeth to palpation
- Malaise
- Nausea
- Headache
- Regional lymphadenopathy and facial or neck swelling
- Difficulty opening the mouth or breathing complaints may be present in more serious infections; fever is not usually present if the infection is localized
- Indications of dangerously increasing infection include fever, tachycardia, hypotension, tachypnea, raised tongue and mouth floor, periorbital cellulitis, trismus, elevated white blood cell count greater than 12,000 or less than 4,000, presence of greater than 10% immature neutrophils, lymphadenopathy, and dehydration; CT scan and ultrasound are useful in determining the area of infection and route of spread in more serious dental infections

TREATMENT

- Treatment is dependent on extent of infection and involvement of deep spaces.
- Empiric antibiotic therapy—Amoxicillin–clavulanate, amoxicillin (amoxicillin is considered superior to penicillin [PCN] V), clindamycin, erythromycin, azithromycin, cefoxitin, and metronidazole (highest resistance) are commonly prescribed following abscess drainage.
- Early intubation needed if threat of airway compromise or patient is unstable.
- Obtain Gram stain, aerobic, and anaerobic cultures from the pus.
- A complete blood count (CBC) with differential may help determine severity of infection.
- Obtain blood cultures for patients with toxic presentation.

TABLE 46.1 **Facial Swelling: Region, Location/Cause, and Patient Presentation**

Region	Location/Cause	Presentation
*Sublingual	Mandibular Canine Lateral and medial incisors Premolar First molar	Pain Dysphagia Unilateral elevation of the floor of mouth and/or base of tongue Airway compromise
*Submandibular	Mandibular Second molar Third molar	Pain Swelling—triangle of neck around angle of jaw (below mandible) Trismus Tender to palpation
*Submental	Mandibular Incisors	Pain Firm Midline swelling beneath chin
Retropharyngeal (more common in children of 4 years and younger)	Maxillary or mandibular First molar Second molar Third molar	Stiff neck Sore throat Dysphagia Voice change Stridor (severe case involving mediastinum)
Buccal	Maxillary or mandibular Premolar Molar	Pain Swollen cheeks Trismus
Masticator	Mandibular Third molar	Pain Trismus Large abscess may require intubation while awake (can lead to parapharyngeal space)

*Infection in these areas can lead to Ludwig's angina (sensation of choking and suffocation). The majority of cases originate from tooth infection, with approximately 75% originating from the second or third molar.

- Limited facial x-ray series and ultrasound may help determine area of infection.
- Soft tissue x-rays of neck needed to assess for gas-producing infections and airway encroachment.
- To determine location of abscess and extent of involvement, a CT scan is needed for suspicion of deeper infections, including lymph nodes.
- In maxillofacial infections, extraction of causative tooth has been found to result in faster clinical and biological resolution of infection; consult a dentist or maxillofacial surgeon for tooth extraction.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Extensively large or deep abscesses that may require surgical incision and drainage and general anesthesia

SPECIAL CONSIDERATIONS

- Pediatric patients
    - Conscious sedation may be necessary for deep-seated or difficult-to-manage areas because of movement or severity
- Each case should be considered independently
- Patients who are immunocompromised or have comorbidities, such as organ transplant, HIV/AIDS, diabetes, and/or cancer, should be treated more aggressively and with a lower index of suspicion for abscess and infection

PROCEDURE PREPARATION

Prior to procedure, risk of airway compromise from loose teeth, bleeding, and abscess drainage should be considered and precautionary airway equipment assembled.

- Anesthesia—topical and injectable
- Gauze
- Nonsterile gloves
- Basin for patient to hold and spit into
- Consider handheld wand suction for patient to assist in suctioning oral secretions postprocedure
- Culture swab (culture and sensitivity)

Needle Aspiration

- 3- or 5-mL syringe
- 21-gauge needle
- Hydrogen peroxide and water (50:50 solution)

Incision and Drainage

- Hemostat
- Scalpel (No. 11 or No. 15 blade)
- Normal saline for irrigation
- Packing material (¼-inch gauze; packing is usually unnecessary)
- Fenestrated Penrose drain

PROCEDURE

- Preprocedure antibiotic administration is advised in specific cases (see “Pearls”).
  - Dry oral mucosa
- Apply topical anesthesia (see Chapter 45, Dental Anatomy, Examination, and Anesthetics).
- Perform either a local or nerve block (see Chapter 45, Dental Anatomy, Examination, and Anesthetics).

Needle Aspiration

- Insert needle into fluctuant area.
- Aspirate.
  - If pus is present on needle aspiration, withdraw only one to two drops. This leaves the abscess visible and easier to locate for incision and drainage. If no pus is present, manage medically.
- Withdraw contents.
- Obtain culture.
- Have patient rinse the mouth with hydrogen peroxide and water.

Incision and Drainage

- Consider incision and drainage when pus cannot be retrieved on needle aspiration or when abscess is clinically apparent.
  - After anesthesia make incision in mucosa over the fluctuant area.
    - Consider inserting a Penrose drain. Make the incision large enough to insert a quarter-inch Penrose drain.
    - If Penrose drain is inserted, suture in with silk suture and leave until drainage of pus has resolved.
  - Insert the tip of the hemostat into the incision.
  - Gently perform blunt dissection of the area to break up loculations.
  - Place the culture swab into the incision.

  - Irrigate with normal saline.
  - Have the patient lean forward or to the side to prevent aspiration and choking.
  - Insert packing if the wound is large enough.
- Suture the end of the packing to the mucosa with an absorbable suture to prevent aspiration.

ULTRASOUND GUIDANCE

- Ultrasound may assist in differentiating between abscess and cellulitis in odontogenic and facial space swelling, and in determining depth of abscesses.
- Ultrasound assessment can be helpful in determining extent of abscess borders.

POSTPROCEDURE CONSIDERATIONS

- Pain can usually be managed with acetaminophen or nonsteroidal anti-inflammatory drugs (NSAIDs) in the outpatient setting.
- Infection—Prescribe broad-spectrum antibiotics postprocedure. PCN-class drugs may be ineffective unless the abscess has been drained. Amoxicillin–clavulanate, amoxicillin (amoxicillin is considered superior to PCN V), clindamycin, erythromycin, azithromycin, cefoxitin, and metronidazole (highest resistance) are commonly prescribed following abscess drainage.
- Admit to hospital if patient is unable to handle secretions, airway swelling, unable to take oral medications, has abnormal vital signs, systemic involvement is suspected, and there is need for intravenous (IV) rehydration.

EDUCATIONAL POINTS

- Use frequent warm salt-water rinses or 0.12% chlorhexidine mouth rinses twice daily for unpacked wounds.
- Do not swallow any drainage; spit it out instead.
- Follow soft diet; progress to regular diet as tolerated.
- Provide education regarding the importance of dental hygiene and regular dental evaluations to avoid future dental infections and complications. Brushing and flossing teeth twice a day and antibacterial mouthwash are preventative.
- Avoid sugary snacks between meals and before bedtime.
- Patients with chronic dry mouth should use an oral moisturizing agent to avoid drying of teeth. which increases bacterial growth.
- Discharge planning—NSAIDS and dental follow-up within 1 to 2 days for simple abscesses.

COMPLICATIONS

Differentiation of location of mandibular infections is important in determining the extent of complications.

- Dentocutaneous fistulae
- Acute suppurative osteomyelitis
- Cavernous sinus thrombosis
- Ludwig's angina
  - Usually due to infection of second and third mandibular molars
  - Throbbing pain in involved area
  - Board-like swelling
  - Rapid spread of cellulitis, sublingual, submental, and submandibular spaces
  - Elevation, edema of tongue
  - Drooling
  - Airway swelling, obstruction
- Maxillary sinusitis

- Facial-space swelling
  - Submental
    - Firm midline swelling below chin
    - Infection from mandibular incisors
  - Submandibular
    - Swelling of submandibular triangle of the neck at angle of jaw
    - Tenderness to palpation
    - Mild trismus
    - Caused by mandibular molar infections
  - Sublingual
    - Mouth floor swelling, tongue elevation possible
    - Pain
    - Dysphagia
    - Caused by anterior mandibular tooth infection
  - Buccal
    - Cheek edema
    - Infection of posterior teeth (usually premolar, molar)
  - Retropharyngeal
    - Neck stiffness
    - Sore throat
    - Dysphagia
    - Hot-potato voice
    - Stridor possible
  - Submental, masticator, canine, lateral pharyngeal, retropharyngeal (may be severe)
- Cellulitis
- Osteomyelitis
- Sepsis
- Airway compromise

PEARLS

- Goals of therapy are to treat the dental infection and prevent complications.
- The American Heart Association recommends antibiotic prophylaxis for the following situations:
  - Prosthetic cardiac valve
  - Acquired valve disease
  - Mitral prolapse with regurgitation
  - Previous infective endocarditis
  - Congenital cyanotic heart disease, including defects remaining after repair (and for 6 months postdefect repair)
  - Cardiac transplant patients with valve deficits
  - Pulmonary shunt
  - Cardiac myopathies
- Recommended antibiotic prophylaxis options:
  - Adult
    - Amoxicillin 2 gm by mouth 1 hour before procedure; if IV route, same dose given 30 minutes prior to procedure
  - Pediatric
    - Amoxicillin 50 mg/kg by mouth (PO) 1 hour prior to procedure; if IV route, same dose 30 minutes before procedure
  - For patients with PCN allergy:
    - Adult
      - Clindamycin 600 mg PO/IV 1 hour prior to procedure
    - Pediatric
      - Clindamycin 20 mg/kg PO/IV 1 hour prior to procedure

  - Alternative:
    - Adult
      - Azithromycin or clarithromycin 500 mg PO 1 hour prior to procedure
    - Pediatric
      - Azithromycin or clarithromycin 15 mg/kg PO 1 hour prior to procedure
- Consider child maltreatment if severe dental caries are present in young children. It is required by law to report suspected maltreatment or abuse.
- Consider possible immunocompromised patient with history of multiple abscesses.
- When extensive swelling and cellulitis are present beyond localized swelling at the site of the infected tooth, obtain anteroposterior (AP)/lateral x-rays to rule out airway impingement.
- Consult appropriate interdisciplinary team members early.
  - Dentist for uncomplicated abscesses
  - Oral-maxillofacial surgeon for complicated abscesses
  - Anesthesiologist and otolaryngologist to establish an alternative airway
- When prescribing Augmentin for children, base dosing on the amoxicillin component of the medication.

DENTAL FRACTURE

BACKGROUND

Approximately one-third of all people will experience a dental injury during their life time. Dental trauma is more likely in males, with the most common mechanisms being falls and motor vehicle crashes. Dental trauma includes dental concussions, dental fractures, luxation, and complete avulsion. Treatment is determined by the severity of injury and whether the teeth involved are primary or permanent. Concomitant/associated injuries must be identified, and their treatment triaged by severity and risk to patient. Intraoral lacerations are commonly found in cases of dental trauma and must be carefully assessed for missing teeth and debris and managed along with tooth fracture. Tooth function and infection prevention are top priorities in the care of dental fractures. Appropriate follow-up with dental and other specialties as indicated is of utmost importance.

The crown is the part of the tooth that is visible above the gumline. Crown fractures can be classified as *uncomplicated* or *complicated* and can be placed in a three-category classification system known as the *Ellis classification system* (**FIGURE 46.2**). The Ellis system is used to anatomically describe the depth that a dental fracture extends within a tooth. The significance ranges in severity with Ellis Class I being the least damage and Ellis Class III representing the greatest damage. Including a detailed description of the injury in documentation and during phone consults is the single best method of conveying the condition of the injured tooth and patient status.

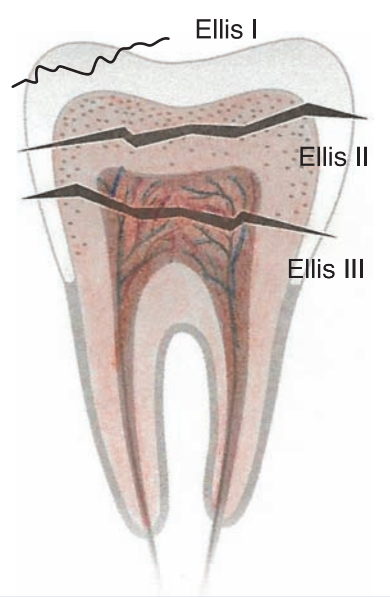

FIGURE 46.2 Ellis classification of tooth fracture.

PATIENT PRESENTATION

Ellis Class I (uncomplicated)—Tooth injury extends through enamel only (crown fractures)

- Teeth usually nontender, without color change, rough tooth edges may be present

Ellis Class II (complicated)—Involves both the enamel and dentin layers

- Teeth tender to touch and air exposure, yellow dentin may be seen on exam

Ellis Class III (most complicated)—Involves enamel, dentin, and pulp layers

- Teeth tender to touch, center of tooth may be pink, red, or bloody
- Ellis Class III is a dental emergency (**FIGURE 46.3**)

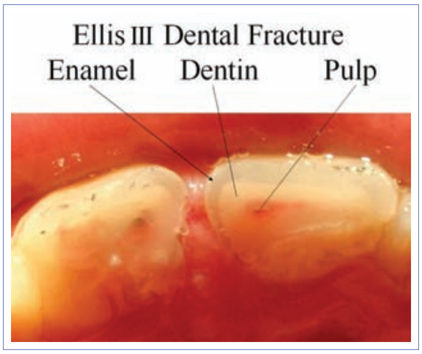

FIGURE 46.3 Ellis Class III fracture.

Source: Thomas, J. J. (2016). Fractured teeth. In A. P. Punjabi (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/82755-overview

TREATMENT

The goals of treatment of dentin fractures are:

- Cover exposed dentin to prevent contamination.
- Provide pain relief.

Ellis Class I—Gently file sharp edges with a dental drill or emery board; dental follow-up for cosmetic purposes.

Ellis Class II—Cover exposed surface with an adhesive barrier (Stomahesive) or 2-octylcyanoacrylate (Dermabond, which decreases sensitivity, provides protective barrier). Dycal® (calcium hydroxide composition) has traditionally been used, however, it may not be necessary and actually may weaken the retention of a later glass ionomer restoration. Administer medication and advise patient to avoid hot and cold food or drink. Follow up with dentist within 24 hours; consider antibiotic coverage (PCN, clindamycin) or glass ionomer.

Ellis Class III—Cover exposed surface with calcium hydroxide composition; immediate dental follow-up, analgesics, antibiotics to cover intraoral flora (PCN, clindamycin) are needed.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Lack of firm adjacent teeth to act as anchors to stabilize mobile teeth

SPECIAL CONSIDERATIONS

- Consider nonaccidental trauma especially in children, elderly, and special needs populations.

PROCEDURE PREPARATION

- Topical anesthesia and injectable anesthesia (see Chapter 45, Dental Anatomy, Examination, and Anesthetics)
- Gauze
- Nonsterile gloves
- Basin for patient to spit in
- Calcium hydroxide $CaOH_2$, zinc oxide, or glass ionomer composites
- Dental spatula
- Tongue depressor (if dental spatula is not available for mixing the composite)
- Cotton-tipped applicators (if dental spatula is not available for application onto tooth)
- Aluminum foil
- Emery board

PROCEDURE

Ellis I

- Smooth rough surface with emery board.

Ellis II and Ellis III

- Dry oral mucosa—have patient gently bite down on gauze pad to absorb moisture.
- Apply topical anesthesia.
- Perform either a local or nerve block.
- Mix the catalyst and base of the composite material as directed on the label with the dental spatula (1:1 ratio).

- A tongue depressor can be used in place of a spatula.
- Dry the tooth—instruct patient to breathe through the mouth while gently biting on gauze pad or connect oxygen tubing to air or oxygen on high flow and point to surface of tooth to dry. The fracture must be dry to ensure adherence of $CaOH_2$.
- Apply the mixture to the tooth with the dental spatula.
- Allow the mixture to dry per the composite material instructions (usually a few minutes).
  - Aluminum foil can be placed on the top of a cap, although this is not necessary if referral to the dental specialist is within 24 hours (**VIDEO 46.1**).

VIDEO 46.1 Video demonstrating application of Dycal.

Source: Peng, L. F. (2018). Dental infections in emergency medicine. In J. Burgess (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/763538-overview

POSTPROCEDURE CONSIDERATIONS

Aspiration/Ingestion

- Tooth and tooth fragments have the potential to be swallowed or aspirated. Care should be given to avoid this.

EDUCATIONAL POINTS

- Use of mouthguards for sports is important as they prevent many dental injuries.
- Primary teeth are not replaced if avulsed, permanent teeth are replaced.
- Preservation and restoration of the injured tooth is the primary goal of treatment in dental trauma.
- Eat soft foods.
  - Avoid chewing on the affected side/tooth.
  - Risk of pulp necrosis, color change, and/or root reabsorption with any fracture is a possibility.

COMPLICATIONS

- Pulp death
- Decreased dental arch
- Ankylosis
- Color change
- Abscess
- Disruption of permanent tooth with fracture to primary tooth

PEARLS

- Assess for fracture particles and tooth mobility before proceeding with more invasive evaluation.
- Missing teeth may be aspirated, swallowed, or imbedded in sinuses, gingival tissue, adjacent bone, or within the nasal cavity; x-rays are appropriate when teeth are unaccounted for.
- Dental trauma may result in significant discomfort; perform a dental block when possible prior to manipulating teeth or applying splints.
- Percuss all teeth for sensitivity and mobility.
- Use topical anesthetics sparingly and for only limited periods of time to decrease irritation to gingival tissue and potential for secondary infection.
- Gum lacerations, bony and soft tissue facial injuries may accompany dental trauma.
- Tetanus prophylaxis should be considered in dental trauma based on contamination factors and patient immunization status.
- Expeditious referral to a dentist is key to tooth survival and long-term outcomes.
- Physical abuse must be considered when treating patients with dental trauma.
- Fractures of primary teeth may not require treatment.
- Patients younger than 12 years have higher risk for pulp contamination and should be treated diligently and referred for follow-up with dentist within 24 hours of injury.

DENTAL CONCUSSION, AVULSION, SUBLUXATION, AND LUXATION

BACKGROUND

Facial trauma and contact sports are common sources of dental injuries. Periodontal ligaments are fibrous connective structures that join cementum covering the tooth root as it connects to alveolar bone. Periodontal ligaments have both neural and vascular components. Injury to a periodontal ligament without tooth laxity or displacement is referred to as a *concussion*. Concussed teeth are usually sensitive to percussion but require no treatment. However, patients should be referred for dental follow-up to monitor tooth viability. Other dental luxation injuries include subluxation, lateral luxation, extrusion, and intrusion. **TABLE 46.2** outlines the type, mechanism, and treatment. *Luxation* refers to partial or complete displacement of a tooth from the socket. Luxation injuries occur when teeth are traumatically dislodged from normal position in the alveolus (socket) resulting in disruption of dental ligaments and tissues that hold teeth in place. The direction and force of impact on a tooth are major determinants of the degree of resulting luxation.

Dental trauma resulting in subluxation produces mobility of a tooth without displacement from the alveolar bone. Lateral luxation is fracture of the alveolar bone with lateral displacement of the tooth. Intrusive luxation occurs when the tooth is pushed below the gingiva into the alveolar bone. Extrusive luxation is a partial avulsion in which the tooth appears elongated and is excessively mobile sustaining some into the degree of separation from the periodontal ligament but leaving alveolar bone intact. Left untreated, luxation injuries may result in necrosis or infection of pulp tissue, resulting in inflammation, resorption, and root destruction.

Dental avulsion describes a tooth that has come completely out of the alveolar socket. This condition is an absolute dental emergency warranting immediate evaluation and treatment. Dental ligament cells, bone, and gingival tissues are injured with this trauma, including potential damage to nerves and blood supply to the tooth. Survival of the tooth is directly related to the amount of time the tooth remains out of the socket. When multiple teeth are found mobile or dislocated on exam, alveolar fractures are likely and emergency management by a dentist or oral surgeon is necessary.

PATIENT PRESENTATION

- Pain
- Mobile tooth/teeth
- Missing tooth/teeth
- Bleeding

TABLE 46.2 Luxation Categories: Type, Mechanism, and Treatment

Type	Mechanism	Treatment
Extrusive	Tooth lifted up partially out of socket	Splint Dental referral
Intrusive	Tooth pushed down into the socket The apex of the tooth may be crushed or fractured	Radiographs Dental referral within 24 hours
Lateral	Tooth displaced laterally—may be facial, lingual, or medial May be associated with alveolar wall injury	Splint Dental referral within 24 hours
Complete	Tooth forced completely out of socket Also known as *avulsion*	Supraperiosteal block Replace tooth in socket Splint or temporary suture Immediate dental referral Soft or liquid diet depending on severity and treatment Antibiotic prophylaxis

TREATMENT

Treatment of dental subluxation and luxation injuries is based on the degree of tooth mobility and extent of injury. The goals in treatment of luxation injuries are to secure the injured tooth to normal position as soon as possible, prevent malocclusion, and salvage tooth function, with dental follow-up transpiring within 24 hours of injury. Pulp and alveolar ligament necrosis as well as color change can result from the trauma.

Subluxation of a primary tooth should not require any intervention unless the tooth is interfering with occlusion. Temporary stabilization of grossly mobile tooth/teeth can be accomplished by applying periodontal paste (Coe-Pak) until definitive care by a dental specialist within 24 hours of injury. Primary teeth sustaining an avulsion injury should not be replaced to avoid interference with eruption of permanent teeth, development of infection, or development of craniofacial abnormalities. However, avulsion of permanent teeth requires immediate attention with replacement of the tooth/teeth into their respective socket(s). Alveolar ligament cells can begin to die within 60 minutes after injury. Commercially available transport suspensions can increase viability of avulsed teeth prior to reimplantation. Rapid immersion (within 10 minutes outside of the mouth) of the tooth in transport media can significantly increase the length of time the tooth is viabile prior to reimplantation. If transport media is not readily available, consider asking the patient to place the tooth in the saliva of his or her mouth unless maturity or cognitive function make this method of preservation unsafe. Patients should be forewarned of the risk for aspiration or ingestion of the tooth if they elect to use this method prior to placement in transport medium or reimplantation. Transport medium is preferred over placing the tooth in the patient's cheek due to presence of bacterial flora and low osmolalityof saliva (**TABLE 46.3**). When feasible, prehospital reimplantation of the tooth is preferable.

The use of periodontal paste to splint the tooth/teeth into place as well as a temporary suture technique are discussed in this section.

TABLE 46.3 **Common Commercial and Other Acceptable Transport Media**

Transport Media	Manufacturer
Milk	
Hank's Balanced Salt Solution	Thermo Fisher Scientific, Waltham, MA
Save-A-Tooth	Phoenix Lazarus, Portland, OR
EMT Tooth Saver	Smart Practice, Inc., Phoenix, AZ
Cell culture media	
Water	

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Tooth replacement should not be undertaken in the presence of:
  - Facial fractures or socket lacerations
  - Avulsed teeth that are also fractured
  - Severe maxillofacial trauma/injury
  - Extended time following complete luxation
  - Gross contamination
  - Severe periodontal disease and multiple decayed teeth
  - When management of displaced teeth poses risk of inhalation

In unconscious patients, and those with head injuries, cervical spine injuries, or medical emergencies, these other injuries take priority over treatment of avulsed teeth.

Chest x-ray is mandatory in presence of these concomitant injuries to assess for avulsed fragments.

SPECIAL CONSIDERATIONS

- Immunocompromised patients, patients with diabetes

PROCEDURE PREPARATION

Procedure 1: Replacing the Tooth/Teeth in the Socket

- Sterile gloves
- Gauze
- Absorbent pads
- Topical and supraperiosteal block materials (see Chapter 45, Dental Anatomy, Examination, and Anesthetics)
- Frazier suction tip
- Suction apparatus
- Sterile normal saline

Procedure 2: Splinting

- Nonsterile gloves
- Gauze
- Lubricant
- Periodontal paste (Coe-Pak™)

Procedure 3: Temporary Suture

- Suture kit
- Gauze
- Sterile gloves
- Absorbable suture material

PROCEDURES

Procedure 1: Replacing the Tooth/Teeth in the Socket

- If the tooth is not already in transport medium, place it there until ready to reimplant.
- Administer topical, local anesthetic and supraperiosteal block (see Chapter 45).
- Assess oral cavity for trauma (i.e., fracture, laceration, other missing teeth; if alveolar fracture or alveolar ridge laceration, do not reimplant).
- Gently suction the socket for blood clots, debris, being careful not to suction the wall of the socket (clot should be removed before reimplantation).
- Irrigate the area gently with sterile normal saline.
- Gently rinse the tooth with sterile normal saline for 10 seconds maximum, holding it by the crown only.
- Never scrub or rub the tooth, especially the root.
- Gently, but firmly, replace the tooth in the socket.
  - Instruct the patient to bite down gently on gauze to aid in positioning tooth.
- The position does not have to be perfect but should be anatomically correct.
- Splint or suture if the tooth is too mobile after insertion.

Procedure 2: Splinting

Splinting is used for grossly mobile or replaced tooth/teeth.

- Replace the tooth/teeth in the socket as described previously.
- Mix the periodontal paste per the instructions.
- Mix base with catalyst to make a moderately sticky paste.
- Completely dry the enamel and gingiva with gauze.
- Place lubricant on gloved fingers.
- Place the paste over the affected tooth/teeth and the adjacent teeth.
- Be sure you apply the paste to the grooves between the teeth (**FIGURE 46.4**).

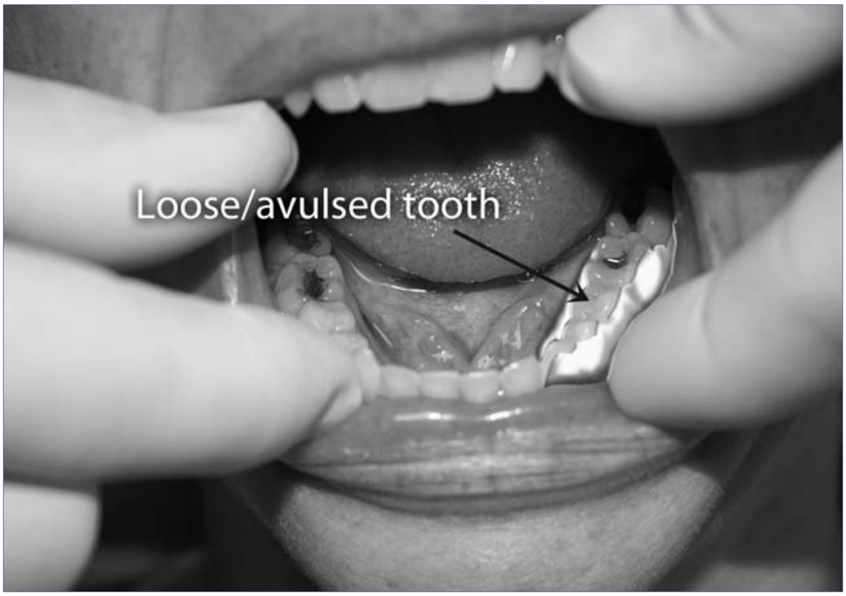

FIGURE 46.4 Securing loose/avulsed tooth with compound.

Procedure 3: Temporary Suture

- Replace tooth/teeth in the socket as described previously.
- Insert the suture needle into the gingiva at the border of the replaced tooth.
- Bring the suture straight down behind the tooth, coming out in front of the tooth.
- Cross the front of tooth with the suture.
- Insert the suture needle into the gingiva on the opposite tooth border.
- Bring the suture straight down behind the tooth, coming out in front of the tooth.
- Cross the front of tooth again with the suture.
- Tie a square knot (**FIGURE 46.5**).

POSTPROCEDURE CONSIDERATIONS

If the tooth/teeth do not remain in place or are too mobile with splinting, then the temporary suture technique should be used. The patient should be medicated for pain and prescribed antibiotics (e.g., PCN or clindamycin) especially if tooth contamination occurred.

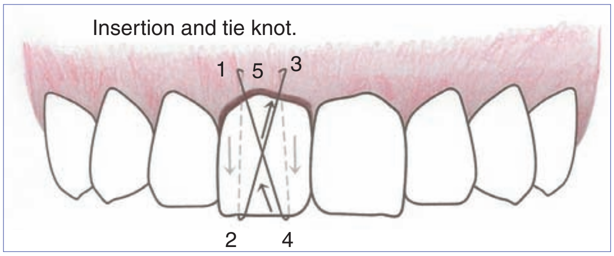

FIGURE 46.5 Temporary suture.

EDUCATIONAL POINTS

Minimally mobile tooth/teeth:

- Soft diet up to 2 weeks
- Dental follow-up within 24 hours

Grossly mobile or complete luxations:

- Liquid to soft diet until dental follow-up
- Urgent dental follow-up

General Points

- Avoid pacifier use, digit sucking, and straw use for drinking.
- Avoid dental flossing until advised by dentist to resume.
- Gently brush with soft toothbrush.
- Gently swish and expectorate chlorhexidine 0.12% mouth rinse for permanent teeth.
- Monitor for pulp necrosis (tooth discoloration, local abscess).
- Immediate dental follow-up if fever, facial swelling, increased pain develop; return to ED if immediate dental access not possible.

COMPLICATIONS

- Failure of temporary composite splint
- Difficulty removing temporary splint material
- Loss of tooth/teeth
- Decreased dental arch
- Ankylosis
- Color change
- Damage to enamel
- Abscess
- Disruption of permanent tooth with fracture to primary tooth

PEARLS

- Mechanism of injury must be considered with dental trauma. Head injury and physical abuse should be considered with any patient sustaining dental injury.
- Rapid assessment and treatment of dental trauma is crucial to positive long-term outcomes. Survival of injured teeth is time sensitive.
- If not addressed in a timely manner, dental injury may incur associated financial burdens related to poor results and outcomes.
- Always be honest with the patient and/or parent about the potential outcome.

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CHAPTER 47

Peritonsillar Abscess

Harry J. Goett

BACKGROUND

Peritonsillar abscess (PTA) is an infection in which purulent fluid collects ***between*** the tonsillar capsule and the pharyngeal constrictor muscles. PTA is the most common deep space infection of the neck with an annual incidence rate of approximately one to four per 10,000. Those between the ages of 10 and 40 years are most commonly affected, and smokers are at increased risk of PTA. It is rarer in preschool-age children, as the lymph tissue is predominantly located in the retro pharynx, thus accounting for the prevalence of retropharyngeal abscesses. Most pediatric cases will be seen in teens (rare in patients younger than 12 years old). The infection has traditionally been attributed to sequela of tonsillitis although primary infection/blockage of the Weber's glands, which are mucous minor salivary glands located in the soft palate superior to the tonsils in the supratonsillar space, has been proposed as the primary etiology of PTA. A combination of these mechanisms, whereby bacteria initially infect the tonsillar mucosa and spread via the salivary duct system of the Weber's glands to the peritonsillar space forming an abscess, may be the most likely etiology.

PTA most often occurs in the superior pole of the peritonsillar space but may also be found in the mid- and lower/inferior poles (**FIGURE 47.1**). The differential diagnosis should include tonsillitis, peritonsillar cellulitis, parapharyngeal abscess, retropharyngeal abscess, Ludwig angina, internal carotid artery aneurysm, tracheitis, infectious mononucleosis, cervical adenitis, epiglottitis, neoplasm, leukemia, and lymphoma. Infectious causes present and progress more rapidly than chronic etiologies. ***Any pulsatile or chronic mass should be investigated with imaging prior to intervention***. Left untreated, PTA may potentially progress to airway obstruction, sepsis, thrombophlebitis, complicated deep neck infections, mediastinitis, and invasion of the carotid artery.

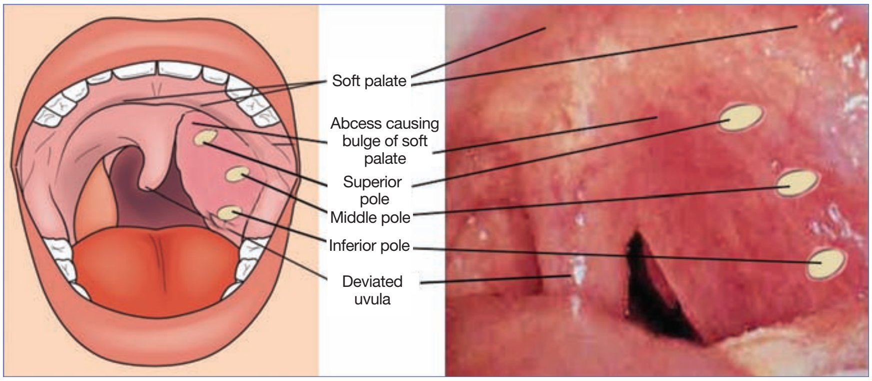

FIGURE 47.1 Location of PTA. Note, as per the literature, 70% of PTAs are located in the superior pole.

PTA, peritonsillar abscess.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

Anatomy

During embryonic development, the palatine tonsils arise from the second pharyngeal pouch as buds of endodermal cells. Each tonsil consists fundamentally of an aggregation of lymphoid tissue underlying the mucous membrane between the palatine arches. They continue to grow until between the ages of 6 and 7 years when they reach their maximum size and then slowly decrease in size until around the age of 65. There are two palatine tonsils, each located on the lateral walls of the oropharynx that lie within a depression between the anterior and posterior tonsillar pillars. ***The tonsillar pillars are composed of glossopalatine and pharyngopalatine muscles and aid in swallowing***. Weber's glands, posterior to the tongue, assist in clearing debris from the tonsils. ***It is important to note the proximity of the carotid sheath, which encompasses the carotid artery and jugular vein, posterior to the palatine tonsils and the peritonsillar space*** (**FIGURE 47.2**).

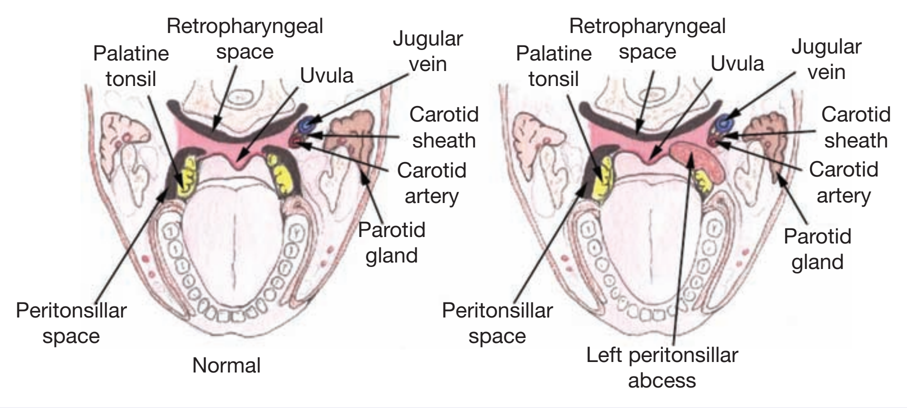
Retropharyngeal space
Palatine tonsil
Uvula
Jugular vein
Carotid sheath
Carotid artery
Parotid gland
Peritonsillar space
Normal
Retropharyngeal space
Palatine tonsil
Uvula
Jugular vein
Carotid sheath
Carotid artery
Parotid gland
Peritonsillar space
Left peritonsillar abcess

FIGURE 47.2 Anatomy of oral pharyngeal area with corresponding vascular structures, glands, important potential spaces (*represented by black area*) and palatine tonsil. Note that when a PTA develops, it does so in the potential space lateral to the tonsil and as such the ultrasound probe/needle needs to be directed accordingly.

PTA, peritonsillar abscess.

Microbiology

PTA is most often a polymicrobial infection; 90% of cases are mixed aerobic and anaerobic infections with multiple infectious species that warrant broad-spectrum antibiotic therapy. The common organisms found in PTA include:

AEROBIC BACTERIA

- ***Group A*** *Streptococcus*
    - Most common up to 30%
- ***Corynebacterium***
- *Staphylococcus aureus*
- *Streptococcus milleri*
  (*S. intermedius, S. anginosus, S. constellatus*)

ANAEROBIC

- *Fusobacterium*
- *Prevotella*
- *Bacteroides*
- *Peptostreptococcus*

PATIENT PRESENTATION

- Sore throat, usually unilateral
- Dysphagia
- Odynophagia
- Voice changes
- Fever
- Drooling
- Neck pain
- Otalgia (affected side)
- Headache

Clinical Findings

- ***Trismus***
    - Inflammation of masseter muscles induces a sustained contraction (glossopalatine and pharyngopalatine muscles comprising the palatine arches)
- Voice changes—"Hot-potato" voice
- Unilateral swelling and displacement of inferior tonsil and soft palate toward midline
- ***Deviation of uvula to the contralateral side of swelling is often present but not diagnostic***
- ***Anterior cervical lymphadenopathy***
- Erythematous mucosa
- Purulent exudate

Laboratory Testing

Depending on clinical presentation, patient medical history, and medications, the clinician may consider obtaining a complete blood count, basic metabolic panel, coagulation studies, and mononucleosis screening.

IMAGING

Ultrasound

- Fast and reliable bedside imaging modality to diagnose PTA and guide drainage
- Can differentiate PTA from cellulitis
- Intraoral approach preferred although transcervical imaging may be appropriate for patients with severe trismus
- Well tolerated by patients

CT

- Not standard of care and usually unnecessary in uncomplicated cases
- May be beneficial in identification of complicated infection beyond the peritonsillar space, especially for the patient with disproportionate presentation with clinical findings
- Scan with intravenous contrast

MRI

- Improved soft tissue detail as well as assessment of carotid sheath are advantages; however, this modality is costly, time-consuming, and not widely available.

TREATMENT

Drainage of PTA and treatment with penicillin are curative in most cases. ***Needle aspiration is as equally effective as incision and drainage***.

- The literature has shown that 85% of patients were effectively treated with outpatient needle aspiration and oral antibiotics (Ophir, Bawnik, Poria, Porat, & Marshak, 1988). Antibiotics that may be considered include:
  - Oral
    - Penicillin VK
    - Amoxicillin/clavulanate
    - Third-generation cephalosporin plus metronidazole
    - Clindamycin
  - Intravenous
    - Penicillin G
    - Ampicillin/sulbactam
    - Third-generation cephalosporin plus metronidazole
    - Pipercillin/tazobactam

Pain and Fever Management

Nonsteroidal anti-inflammatory drugs (NSAIDs) and acetaminophen are mainstays of fever and pain management. Glucocorticoids are frequently given although clinical evidence is mixed on its efficacy. In a meta-analysis of three heterogeneous randomized controlled trials (RCTS) totaling 153 patients, Hur, Zhou, and Kysh (2018) have shown that steroid administration significantly decreased body temperature compared to placebo. Pain scores, mouth opening, time to painless oral intake, and duration of hospitalization were significantly improved in only one or two of the three RCTs between the steroid and control group. No adverse side effects from steroid administration were reported. Authors concluded that using steroids as an adjunct therapy to the treatment of PTA may result in faster recovery, al though further investigation with larger RCTs and standardized outcomes are warranted.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Severe trismus
- Findings concerning for carotid artery aneurysm
- Coagulopathy
- Uncooperative patient

SPECIAL CONSIDERATIONS

- Immunocompromised and diabetic patients
- Very young and the elderly

PROCEDURE PREPARATION

Intraoral Ultrasonography

- Ultrasound machine with a high-frequency (4–9 MHz) intracavitary transducer
- Transducer (probe) cover
- Small amount of gel

Needle Aspiration

The following should be assembled in preparation regardless of technique selected:

- Skin cleanser
- Sterile gown

- Sterile gloves
- Mask
- Face shield
- Sterile towels/drapes
- Lighting
    - Headlamp
    - Lighted laryngoscope blade
    - Lighted vaginal speculum
    - Overhead light
- Tongue blade or laryngoscope with Mac #3 or #4 blade
- Gauze
- Wall suction with Yankauer tip
- 25- to 27-gauge long needle (1″ or longer)
- 16- to 18-gauge long needle (spinal needle if available)
- 3-mL syringe
- 10-mL syringe
- Topical anesthetic spray (Cetacaine®)
    - Local anesthetic often not used/required
- Injectable anesthetic (Lidocaine 1% with epinephrine; **FIGURE 47.3**)

Incision and Drainage

- Same as needle aspiration
- No. 11 scalpel

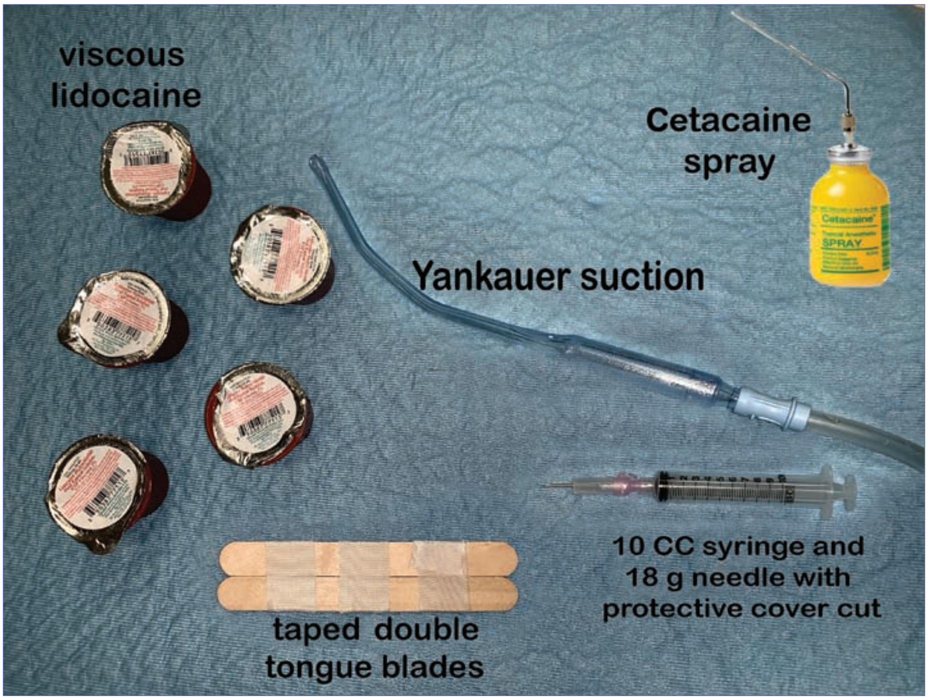
viscous lidocaine
Cetacaine spray
Yankauer suction
10 CC syringe and 18 g needle with protective cover cut
taped double tongue blades

FIGURE 47.3 Proper patient anesthesia before needle aspiration of a PTA. The sound made by the repeated gurgling of viscous lidocaine cannot be underemphasized.

PTA, peritonsillar abscess.

PROCEDURE

Intraoral Ultrasonography

- Explain procedure to the patient.
- Place a protective sheath or condom over the transducer.
- Place a small amount of gel on the inside and outside of the sheath/condom.
- Spray topical anesthetic on the mucosa of the posterior pharynx.
- Injectable anesthetic should not be necessary for ultrasound evaluation of the peritonsillar tissue, but may be necessary if needle aspiration and/or incision and drainage are indicated.
- Place the transducer over the tonsillar tissue (**FIGURE 47.4**).
- Scan in a systematic manner along two orthogonal planes to visualize the tonsil and peritonsillar tissue.
- If fluid collection is present, it should be apparent (**FIGURE 47.5**).
- Next, evaluate the soft palate in both a sagittal and transverse plane to determine the superior and inferior ends of the abscess, the depth, and proximity to the carotid sheath and artery.
  - Color Doppler should now be used to identify the depth of the carotid artery (**FIGURE 47.6**).
- A comparison to the contralateral tonsil can be performed.
- If an abscess is identified, needle aspiration or incision and drainage should be done using static ultrasound guidance. It is often difficult to do dynamic ultrasound guidance due to limited intraoral space. Transcervical ultrasound has been used for dynamic ultrasound guidance with the needle approaching from the opposite direction.
  - Give particular attention to the footprint and angle of the intracavitary transducer to guide injection of anesthetic and needle aspiration/incision and drainage.
- If intraoral ultrasound cannot be performed due to trismus, consider using a *transcutaneous/transcervical* approach using a high-frequency linear transducer to scan the pharynx.
  - May not be as accurate in diagnosing and guiding treatment of a PTA.
- If there is concern for more extensive deep space infection in the neck, CT imaging may be considered.

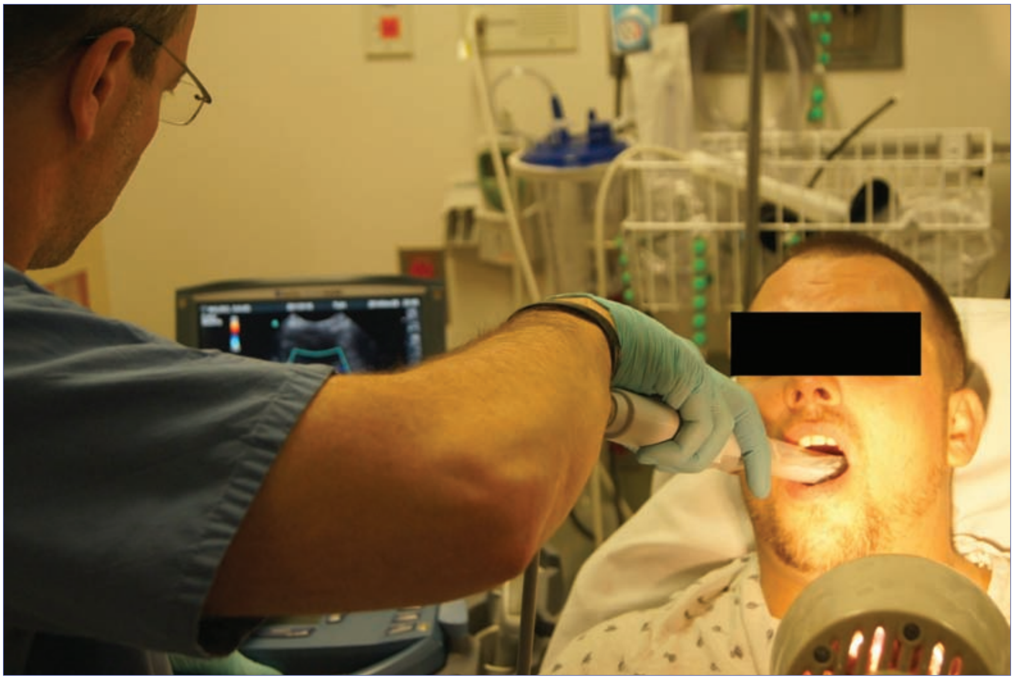
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FIGURE 47.4 Ultrasound identification of a possible PTA. Note that one should not use a needle to find the PTA, as this is what the ultrasound does.

PTA, peritonsillar abscess.

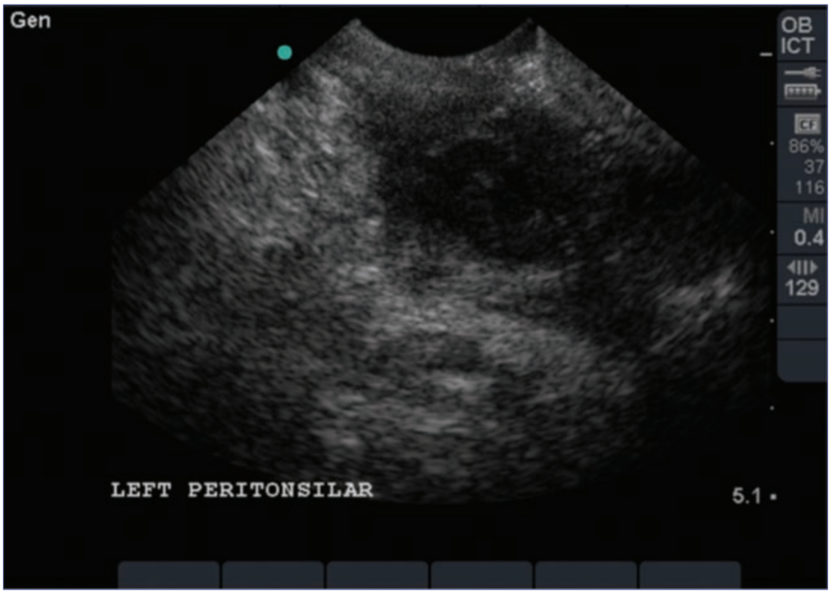

Gen
OB
ICT
86%
37
116
MI
0.4
129
LEFT PERITONSILAR
5.1

FIGURE 47.5 Left PTA represented by the circular hypoechoic area. Note the PTA is always deep and lateral to the palatine tonsil, which gets pushed medially by the abscess.

PTA, peritonsillar abscess.

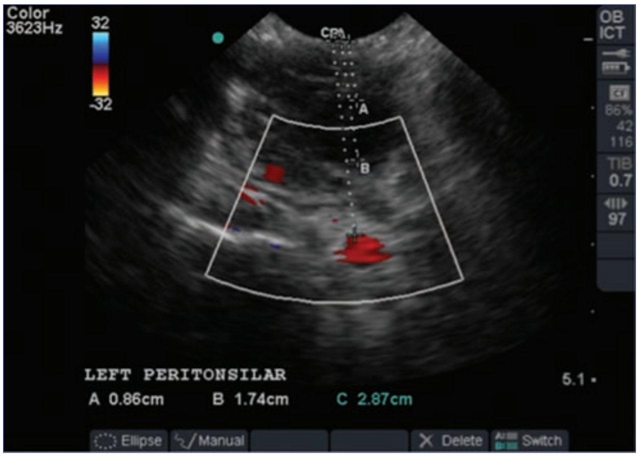

Color
3623Hz
32
-32
CPA
A
B
OB
ICT
86%
42
116
TIB
0.7
97
LEFT PERITONSILAR
A 0.86cm
B 1.74cm
C 2.87cm
5.1
Ellipse
Manual
Delete
Switch

FIGURE 47.6 Note the quantitative depth of the carotid sheath and ensure the needle cap is cut below this depth.

Equipment

- Taped double-blade tongue depressors
- Topical anesthetic spray
  - Local anesthetic often not used/required
- Viscous lidocaine
  - Gargle and spit
- Yankauer suction or smaller Frazier suction
- 10-cc syringe and 18-gauge needle with protective cover cut
- Ultrasound

Needle Aspiration

Several methods may assist with visualization of the peritonsillar area. You can use double-taped tongue blades, a curved laryngoscope blade (**FIGURE 47.7A**), or a dismantled vaginal speculum with light to hold the tongue out of the way and give light intraorally. Use of a patient-held laryngoscope blade has the advantage of providing additional lighting, minimizing inadvertent stimulation of the gag reflex, and distracting the patient from the procedure.

- Place a patient drape over the patient's chest to just under the chin.
- Adjust lighting to assist with proper visualization of the patient's posterior pharynx.
- Position yourself so you can easily visualize the area and manage the needle and syringe safely.
- If not utilizing an ultrasound-guided technique to locate the abscess, consider manually palpating the peritonsillar area to ascertain the fluctuant area if it is not evident on direct visualization.
- Have patient gargle viscous lidocaine for up to 1 minute; repeat at least 2 to 3 more times.
- Apply topical anesthetic (e.g., Cetacaine) to fluctuant area.
- If injectable anesthetic is required, use the 25- to 27-gauge long needle to inject a small amount of anesthetic into the mucosa overlying the abscess (**see FIGURE 47.7B**).
  - Typically, 0.5 to 1 ml of anesthetic is sufficient.
- Attach the long 16- to 20-gauge needle to the 10-mL syringe.
  - If ultrasound examination revealed an abscess larger than 10 cc, consider using a larger syringe.
- Remove the needle cover and cut off the distal portion of the cover (**FIGURE 47.8**). If ultrasound was used, cut off the amount needed to penetrate to the center of the abscess cavity. Otherwise, limit the exposed portion of the needle to 1 cm.
- Replace the now-cut needle cover over the needle attached to the syringe.
  - This will help avoid overpenetration of the needle and risk of carotid sheath penetration and injury.
  - ***Studies have shown that the carotid artery's depth is an average of 25 mm deep to the pharyngeal wall, though anatomical variations exist.***
  - ***In the presence of a PTA, the carotid is often deeper, 40 mm in one study***.
- Insert the needle into the area of fluctuance along the sagittal plane, or in the plane previously demonstrated using the intracavitary ultrasound transducer (**see FIGURE 47.7C**).
  - ***Do not angle laterally toward the carotid artery and do not insert the needle into the tonsil itself—the needle should be in the peritonsillar space only.***
- Have an assistant stand on the other side of the bed holding a Yankauer suction device.
- Aspirate and remove as much purulent fluid as possible from the abscess cavity (**VIDEO 47.1; FIGURE 47.7D**).

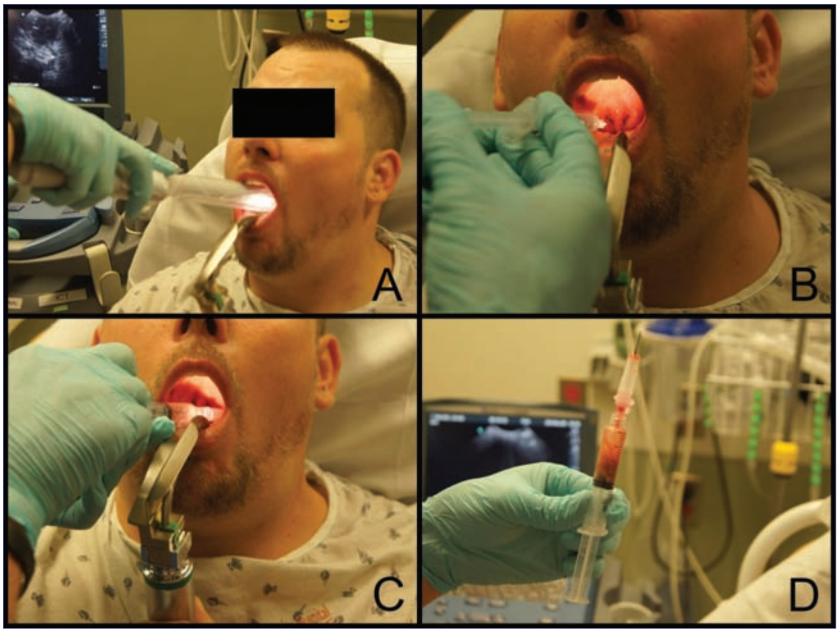


FIGURE 47.7 Sequential steps in needle aspiration of a PTA.

PTA, peritonsillar abscess.

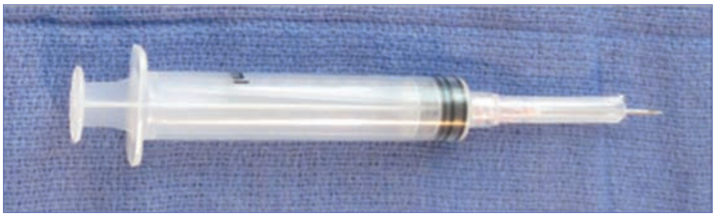
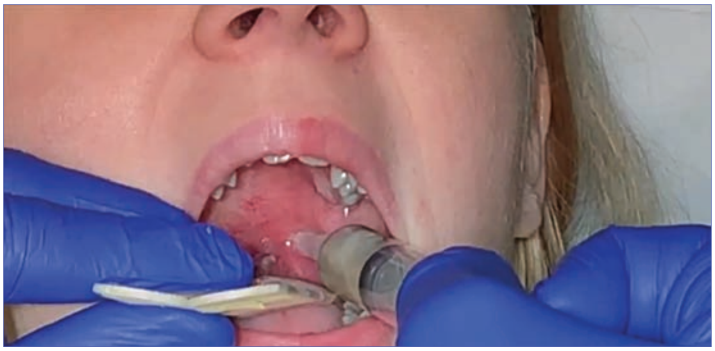


FIGURE 47.8 It is imperative to remove, cut, and reinsert the needle cap in order to protect against inadvertently inserting the needle too deep in regard to the carotid sheath. One can and should use the ultrasound identification and quantitative depth of the carotid sheath for guidance.



VIDEO 47.1 Needle aspiration of a PTA.

- It is normal to remove 2 to 6 mL of purulent fluid from a PTA and it can be common to remove greater than 8 mL (**see FIGURES 47.7D** and **47.9**).
  - When large amounts of pus are removed, there is a higher incidence of abscess recurrence and repeat aspiration may be warranted.
- If no purulent fluid is returned, remove the needle and attempt again in the middle pole and then in the inferior pole of the space (**see FIGURE 47.1**) or reapply the ultrasound probe to ensure correct placement of the aspiration needle.
  - Keep the needle position in the same sagittal plane when redirecting in lower poles.
  - ***Stopping the procedure after a single negative aspiration in the superior pole will miss up to 30% of the cases of landmark-guided aspiration.***
  - Make no more than three attempts.
- Unsuccessful aspiration of purulent fluid does not rule out a PTA and further diagnostic imaging may be warranted.
  - If utilizing ultrasound and an abscess was initially appreciated, consider reevaluating the abscess location with the intracavitary transducer.
  - In one study (Johnson & Stewart, 2005), 60% of otolaryngologists in the United Kingdom used needle aspiration as the primary means of treating a PTA; if needle aspiration failed, 52% would then perform an incision and drainage.

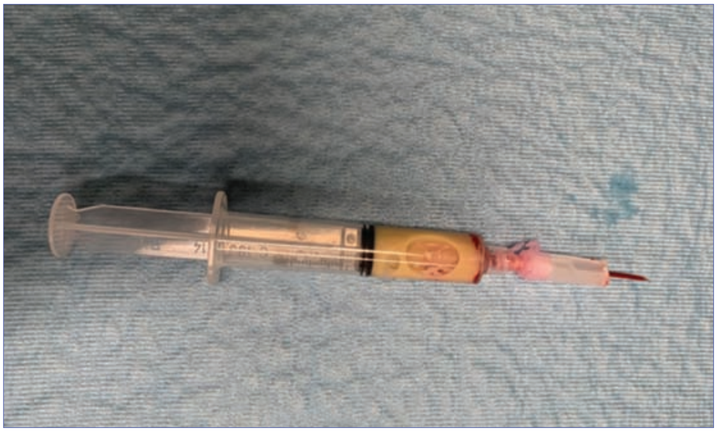


FIGURE 47.9 Needle aspiration of a PTA showing typical purulent return.

PTA, peritonsillar abscess.

Incision and Drainage

- Although typically unnecessary, in select cases, incision and drainage may be warranted.
- Follow the same steps marked with an asterisk used for needle aspiration in the preceding procedure.
- Tape all but the distal end of the scalpel tip to prevent deep penetration (**FIGURE 47.10**).
- Advise the patient that they will notice the flow of pus/blood in the mouth and to expectorate it and not swallow.
- Have an assistant hold the suction tip in the patient's mouth to help with the drainage.
- Incise 0.5 cm of mucosa in a posterior to anterior direction, being careful not to exceed the taped area of the scalpel.
    - ***From the standpoint of potential injury to the carotid artery, medial and superior incisions are safer.***
- A stab incision with the No. 11 scalpel blade is also acceptable.
- Take the Kelly clamp or hemostat, insert into the opening while the clamp is closed, then gently open the clamp, disrupting any loculations.

POSTPROCEDURE CONSIDERATIONS

Patients should be observed postprocedure for bleeding, reaccumulation of fluid in abscess space, and ability to tolerate oral fluids. Most patients who have had successful evacuation of a PTA may be discharged home with oral antibiotics, pain medication, and otolaryngology (ears/nose/throat [ENT]) follow-up. A minority of patients may require admission for persistent bleeding, further surgical intervention, intravenous antibiotics (toxic patients), intravenous hydration, and pain management. ENT consultation should be considered in patients for whom drainage is unsuccessful but who have a demonstrated PTA on imaging and patients requiring admission.

EDUCATIONAL POINTS

- Up to 10% of appropriately treated PTAs will recur.
- All patients should follow up with otolaryngology (ENT).
- ***Note the abscess is not in the lymphoid tonsil itself, but rather in the peritonsillar space***; hence, do not direct the needle in the tonsil (medial bulge) but rather in the poles (**see FIGURE 47.1**), which represent the area between the lateral tonsillar capsule and the constrictor muscles.
- Although typically unnecessary, parenteral narcotic pain relief and/or minor sedation may be considered for certain patients.
- Seventy percent of PTAs are located in the superior pole.
    - If aspiration is negative, needle aspiration of the other two poles must be attempted.

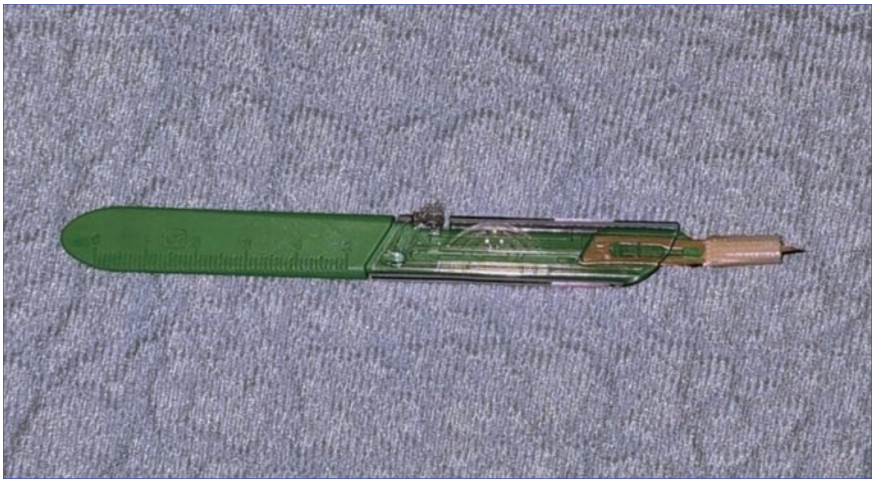


FIGURE 47.10 To prevent inadvertent excessive penetration, the scalpel is taped, except for the tip.

- In the pediatric population most cases are seen in teenagers, as the lymph tissue is located predominantly in the retro pharynx in the younger preschool patients, thus accounting for the prevalence of retropharyngeal abscesses in this age group.
- The incidence of bilateral PTAs is between 3.9% and 6.5%; this can present as a diagnostic challenge as the uvula might not be deviated, which is a common physical exam finding for typical PTAs.

COMPLICATIONS

- Hemorrhage
  - Coagulopathy
  - ***Carotid injury or pseudoaneurysm (obtain emergent ENT and vascular surgery consultation); this dreaded complication has still not been reported in the medical literature though one must remain cognitive of this potential***
    - Be aware of anatomic variants of the internal carotid artery (aka *aberrant carotid artery*; **FIGURE 47.11**). In some patients, the carotid can be much more midline and can be in danger of iatrogenic injury during needle aspiration or incision and drainage.
- Patient aspiration of blood or purulent fluid
- Inadequate treatment of abscess
  - Up to 10% of PTAs initially treated appropriately will recur
  - May cause airway obstruction, tissue necrosis, carotid sheath hemorrhage, extension of infection into deep neck tissue or posterior mediastinum (chest wall)
- Sepsis
- Jugular vein thrombosis
- Carotid artery injury
  - A rare occurrence but extreme care must be given during any drainage procedures.
- Poor healing
- Cervical abscess, cerebral abscess

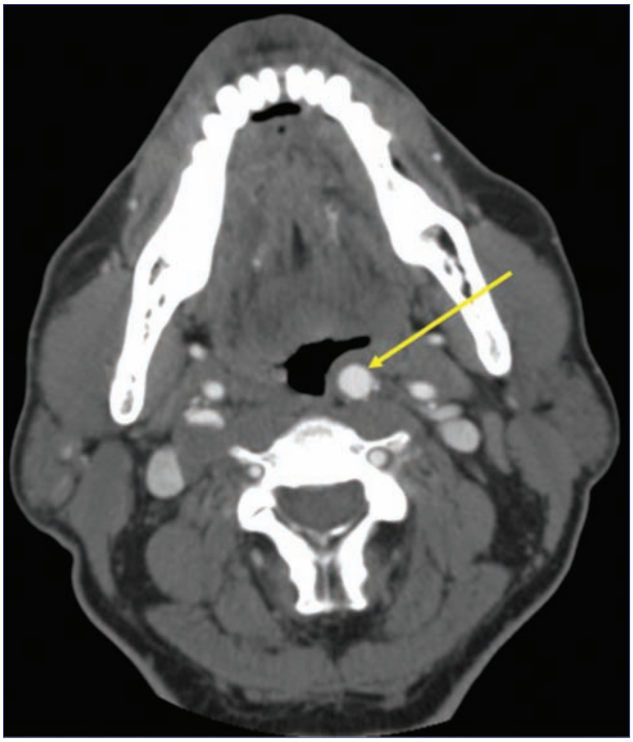


FIGURE 47.11 CT scan with contrast demonstrating a left aberrant carotid artery. This anomaly highlights the importance of using POCUS in identifying the carotid sheath before needle aspiration of a PTA is undertaken.

POCUS, point-of-care Ultrasound; PTA, peritonsillar abscess.

PEARLS

- Uncomplicated PTAs can typically be treated without initial specialty consultation.
- ***Intraoral ultrasound is an effective bedside imaging modality to both diagnose and guide drainage of PTAs.***
- ***Needle aspiration is as effective and better tolerated than incision and drainage of uncomplicated PTAs.***
- Oral penicillin is an appropriate first-line antibiotic in most patients.
- Up to 10% of appropriately treated PTAs will recur.
- Do not angle laterally toward the carotid artery and do not insert the needle into the tonsil itself, as the needle should be in the peritonsillar space only.
- PTAs do not get better with antibiotics as a primary treatment; they get better with drainage (**FIGURE 47.12**).

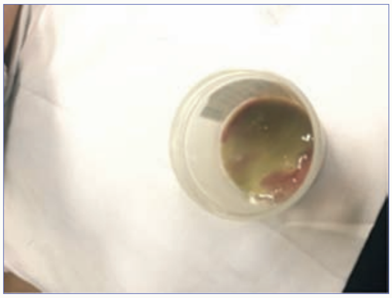


FIGURE 47.12 Contents of an aspirated PTA. Antibiotics alone will not cure this.

PTA, peritonsillar abscess.

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CHAPTER 48

Reducing Mandibular Dislocations

Patrick Cotter

BACKGROUND

Temporomandibular joint (TMJ) dislocation is a painful condition occurring when the mandibular condyle displaces from its normal position in the mandibular fossa. This usually occurs when there is excessive opening of the mandible in such activities as yawning, dental procedures, oral sex, vomiting, or seizures. It may also occur in patients suffering from dystonic reactions to drugs or with genetic disorders associated with joint hypermobility such as Marfan's and Ehlers–Danlos syndromes. Although trauma to the mandible is often associated with fractures, it can result in dislocation with displacement of the mandible posteriorly from a blow to the chin or laterally from a blow to the mandible while the mouth is partially open. Patients who suffer from recurrent TMJ dislocation may require referral for specialist management following reduction.

Prior to describing the mechanisms of mandibular dislocation, a brief overview of TMJ anatomy (**FIGURES 48.1** and **48.2**) and movement is given:

- *Joint type:* Ginglymoarthrodial joint allowing both hinge and gliding movements
- *Articulation*: Articular surface of the temporal bone and the condyle of the mandible
- *Supportive ligaments:* Temporomandibular, sphenomandibular, and capsular ligaments
- *Blood supply:* Superficial temporal branch of the external carotid artery
- *Nerve supply:* Branches of the auriculotemporal and masseteric divisions of the mandibular nerve
- *Movement:* Hinge and glide
    - Movement of mandible involves both TMJs.
    - There is smilar movement in both TMJs during descent, elevation, protrusion, and retraction.
    - Contrary movement occurs in TMJs during grinding and rotation.
        - Elevation or bite—Temporalis, masseter and medial pterygoid muscles
        - Protrusion—Medial and lateral pterygoid muscles

The direction of dislocation of the mandible is described by the position of the mandibular condyle in relation to articular eminence of the temporal bone. Mandibular dislocation commonly occurs in the anterior direction. Much less common are posterior, lateral, and superior directions of dislocation (Malik, Debnah, Adhyapok, & Hazarika, 2017).

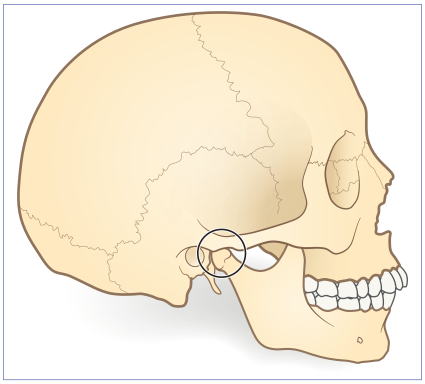


FIGURE 48.1 Temporomandibular joint (TMJ). Note the mandibular condyle sits in the mandibular fossa. In the typical mandibular dislocation, the mandibular condyle moves out of the mandibular fossa and anterior to the articular eminence.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

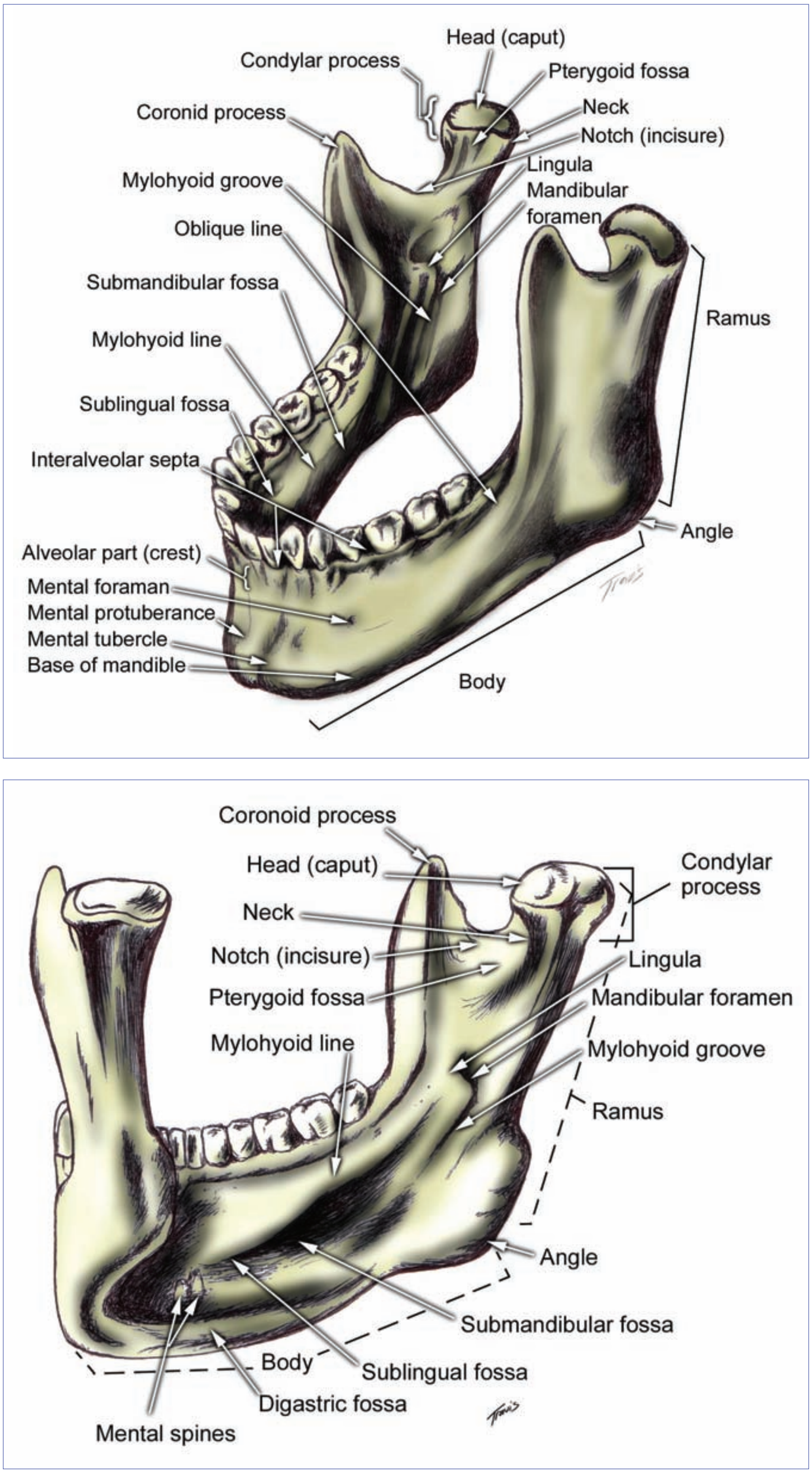

Head (caput)
Condylar process
Pterygoid fossa
Coronid process
Neck
Notch (incisure)
Lingula
Mylohyoid groove
Mandibular foramen
Oblique line
Submandibular fossa
Ramus
Mylohyoid line
Sublingual fossa
Interalveolar septa
Angle
Alveolar part (crest)
Mental foraman
Mental protuberance
Mental tubercle
Base of mandible
Body
Coronoid process
Head (caput)
Condylar process
Neck
Notch (incisure)
Lingula
Pterygoid fossa
Mandibular foramen
Mylohyoid line
Mylohyoid groove
Ramus
Angle
Submandibular fossa
Body
Sublingual fossa
Digastric fossa
Mental spines

FIGURE 48.2 Illustrations depicting mandible anatomy.

Types of Dislocation

Anterior: Mandibular condyle displaces out of the mandibular fossa anterior to the temporal articular eminence. Mandible protrudes with significant underbite.
Posterior: The mandibular condyle is displaced posteriorly out of the mandibular fossa toward the mastoid process. This may result in associated auditory canal injury, condylar neck, or base-of-skull fracture.
Lateral: The mandibular condyle is displaced laterally and superiorly into the temporal space. The patient's chin is deviated to the side. This injury is typically associated with mandibular fracture(s).
Superior: The mandibular condyle is displaced superiorly into the middle cranial fossa. This is a rare form of dislocation and may result in significant injury, including fracture to the mandibular fossa or dislocation of the mandible into the middle skull base. Other associated injuries include facial nerve injury, cranial nerve (CN) VIII injury (which may cause deafness), intracranial hematoma, cerebral contusion, and cerebrospinal fluid leakage (**FIGURE 48.3**).

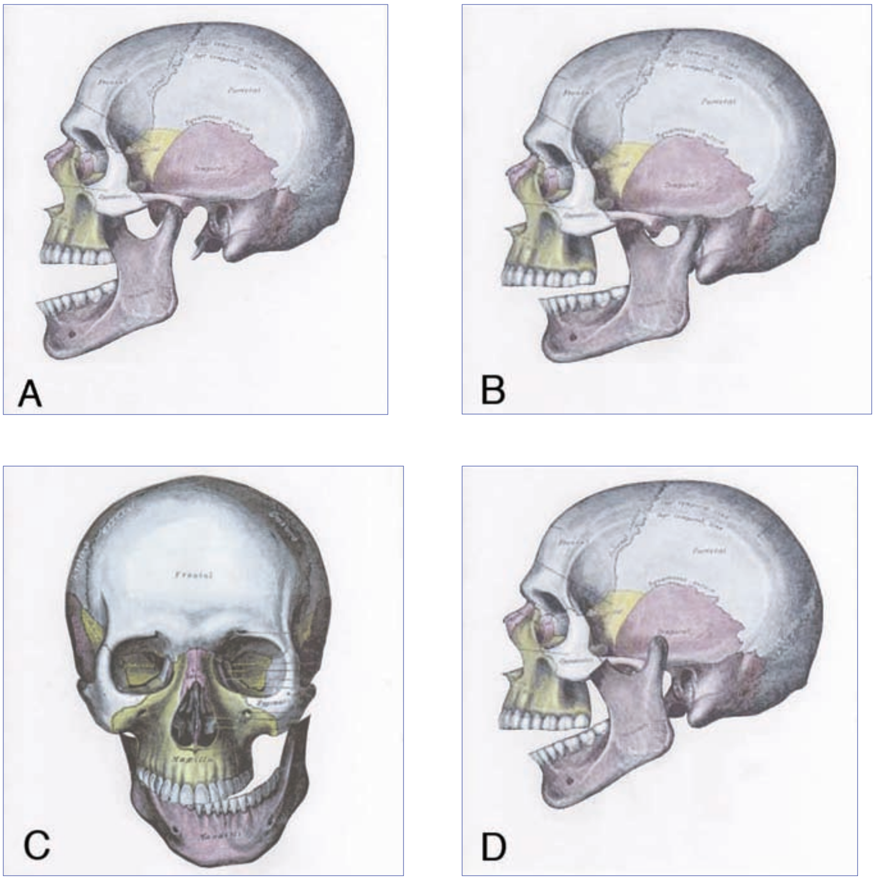


FIGURE 48.3 Types of dislocations: (A) anterior, (B) posterior, (C) superior; (D) lateral.

PATIENT PRESENTATION

- Sudden onset of jaw pain
- Inability to close mouth
- Difficulty speaking with speech sounding garbled
- Difficulty swallowing
- Severe painful contraction of the muscles of mastication (masseter, temporalis, and internal pterygoid) resulting in trismus

Examination

A full head and neck examination should be performed on all patients presenting with mandibular dislocation. This should include assessment of cranial nerves for deficit (CN V and VIII). If the mandibular dislocation was due to trauma, then assessment must include assessing for intracranial injury, base-of-skull fracture, oral and dental injury, and auditory and external auditory structural injury. Care must also be taken to examine for cervical spine injuries and any other nonhead and neck injuries suggested by the mechanism of injury.

INSPECTION

- Lower jaw prominent with significant underbite in bilateral anterior dislocation
- Trismus
- Deformity at TMJs with condyle visible anterior to articular eminence and depression in preauricular area
- Deviation of the chin in unilateral dislocation
- Visible drooling from mouth

PALPATION

- Tender TMJ bilaterally/unilaterally
- Mandibular condyle palpable
- Palpable depression in preauricular area

MOVEMENT

- Minimal mandibular movement
- Unable to close mouth

Tests

- The tongue blade is a quick bedside test that is used to assess the presence of an occult fracture with high sensitivity, especially in trauma; use only if there is no obvious dislocation and patient is able to close the mouth.
  - On one side of the mouth place a tongue blade between the molars.
  - Have the patient bite down on the tongue blade that is between the molars.
  - Twist the tongue blade to attempt to break it. If the patient is unable to hold the tongue blade and/or experiences pain, then the test is considered to be positive. If the patient is able to hold the tongue blade tightly without pain, then the test is considered to be negative.
- *Imaging*: All patients with suspected mandibular dislocation should have imaging of the mandible to assess for fractures. According to Naeem, Gemal, and Reed (2017), a mandibular x-ray series should include three views: posteroanterior (PA), oblique, and lateral views. These are the minimum images used to assess the mandible. If available, an orthopantomogram (OPG) should be taken. It has been reported that this view has a higher sensitivity for detecting a mandibular fracture (92%) than the minimum x-ray series (66%; Chayra, Meador, & Laskin, 1986). Helical CT imaging in some studies have shown 100% sensitivity in diagnosing mandible fractures, compared with 86% sensitivity with panoramic tomography (panorex) imaging. CT with 3D reconstruction (coronal highest sensitivity) is considered the diagnostic tool of choice for the radiographic evaluation and diagnosis of mandible fractures. Mendez and Ness (2018) advocate early reduction without imaging in patients with nontraumatic mandibular dislocation if there is a delay in imaging. Images should also be taken following reduction of the mandible.

TREATMENT

The objective in managing mandibular dislocation is to return the mandibular condyles to their original position. This needs to occur in a timely fashion as lengthy dislocations can increase the difficulty and reduce the accuracy of the reduction (Malik et al., 2017).

A number of reduction methods have been described in the literature. Ardehali, Tari, Bastaninejad, and Amirizad (2016) compared the conventional, wrist-pivot, and the extraoral methods for mandibular dislocation in a randomized controlled trial. In their study, they found that the wrist-pivot method had the highest success rate at 96.7% followed by the conventional method (86.7%) and the extraoral method (66.7%). However, Prechel, Ottl, Ahlers, and Neff (2018), in a systematic review of reduction methods, found that there was a lack of reliable data to advocate one technique over another. This is due largely to methodological issues with the studies such as sample sizes and heterogeneity of the study designs.

Reduction can be performed with or without sedation or local anesthesia. Prior to describing various reduction methods for mandibular dislocation, it is important to consider a number of issues while also preparing adequately for the procedure.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Significant facial, head, or neck trauma
- Mandibular fracture
- Multiple failed attempts at reduction
- Aggressive or uncooperative patient

SPECIAL CONSIDERATIONS

- Uncooperative and anxious patients may require sedation.

PROCEDURE PREPARATION

Procedural Sedation

Procedural sedation is often not required to reduce a dislocated mandible. The advantages of using sedation include reduction in muscle spasm and reduction in anxiety. There are a number of disadvantages to using procedural sedation, including airway risk, adverse drug reactions, and increased length of stay in the department following procedure. When using procedural sedation, the clinician needs to follow their own departmental policy and procedure.

Local Anesthesia

- 25- to 30-gauge needle
- 3- or 6-mL syringe
- Lidocaine 1%
- Skin cleanser

Reduction

- Head rest/support
- Tongue depressor
- Gauze
- Gloves
- Bite block
- Syringe

PROCEDURE

Local Anesthesia

Follow unit policy and procedure.

- Prepare skin in the area anterior to the ear on the affected side using skin-prep cleanser.
- Palpate the preauricular depression created by dislocation of the mandible at the TMJ.
- Insert the needle into the depression, directing the needle anterior and superior (onto the surface of the glenoid fossa).
- Inject approximately 2 mL of lidocaine into the TMJ (**FIGURE 48.4**).

Reduction

CONVENTIONAL METHOD

- Sit patient in a chair with the clinician in front, facing the patient.
- Clinician wraps gauze over their gloved thumbs and places the thumbs on the patient's lower molars.
- Wrap remaining fingers around the angle and body of the mandible.
- The patient should be positioned so that the mandible is lower than the clinicians' elbows.
- Place continuous pressure in a downward and posterior direction on the patient's lower molars (**VIDEO 48.1**).
- Simultaneously, apply upward pressure on the mentum of the mandible with the third and fourth fingers (**FIGURE 48.5**).
- In bilateral dislocation, both sides can be reduced together but it has been reported that it is easier to do one at a time (Ardehali et al., 2016).

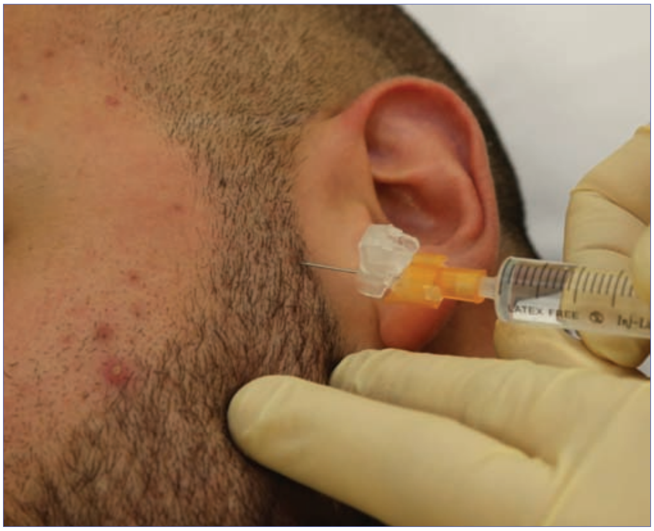
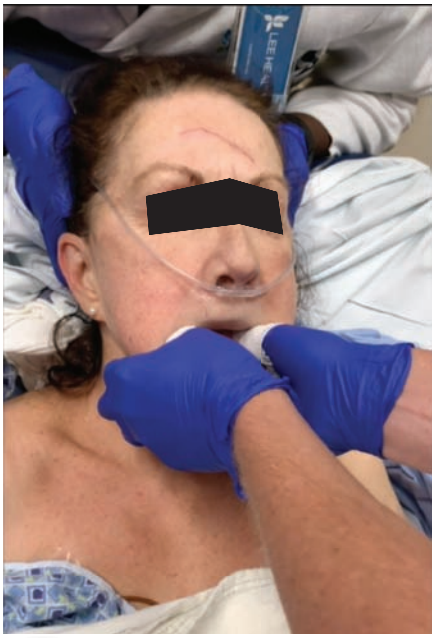


FIGURE 48.4 Photograph showing administration of local anesthesia.

Source: Courtesy of Patrick Cotter.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VIDEO 48.1 Conventional method of mandibular reduction also demonstrating gauze placement around the thumbs.

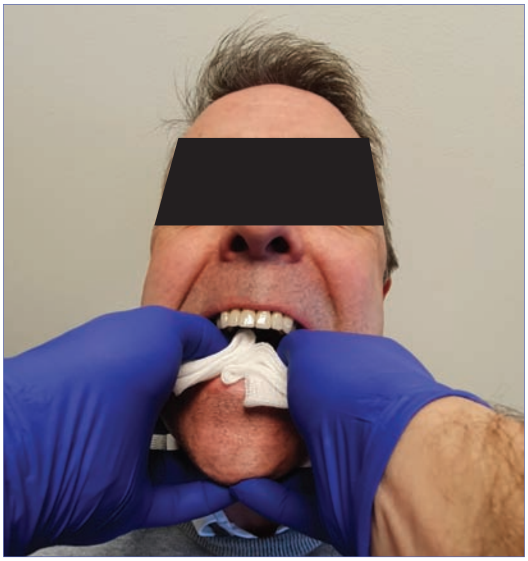
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FIGURE 48.5 Photograph demonstrating the conventional method.

EXTRAORAL METHOD

- Sit patient in a chair with the clinician standing in front, facing the patient.
- On the dislocated side, the clinician places their thumb on the coronoid process and the fingers on the mastoid process.
- On the opposite side, the clinician places the thumb on the malar eminence and the fingers on the angle of the mandible.
- Pull the angle of the mandible in an anterior direction levering against the thumb on the malar eminence.
- Push the coronoid process on the dislocated side posteriorly, levering against the fingers on the mastoid process (**FIGURE 48.6**).

WRIST-PIVOT METHOD

- Sit patient in a chair with the clinician in front, facing the patient.
- Clinician places both thumbs in the submental area and fingers over bilateral lower molars.
- With a grip on the mandible, deviate the wrist in an ulnar direction while slightly flexing the wrist.
- In bilateral dislocation, both sides will reduce together (**FIGURE 48.7**).

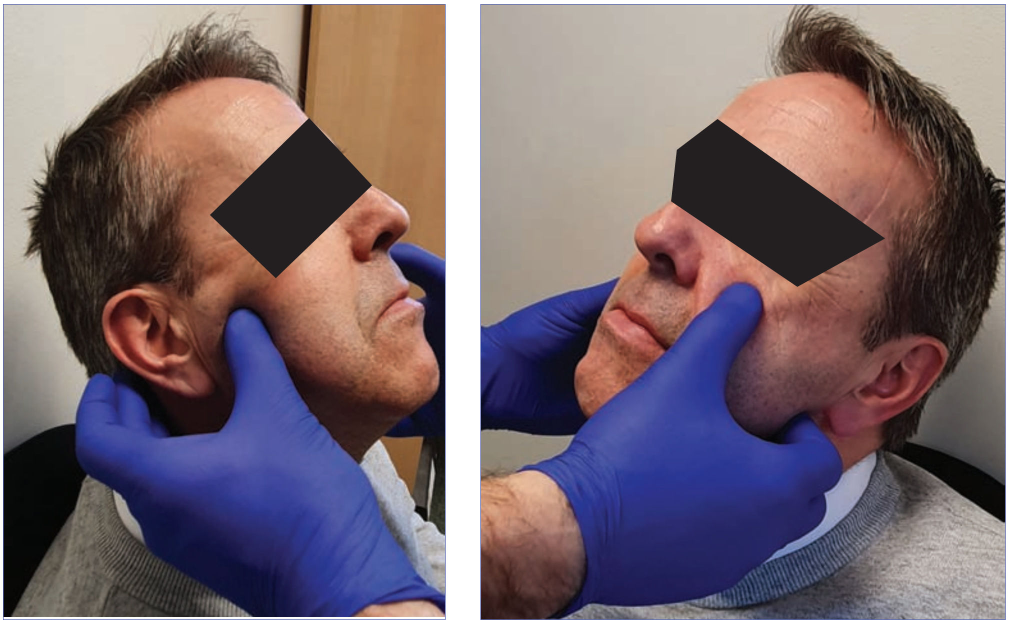


FIGURE 48.6 Photographs demonstrating the extraoral method.

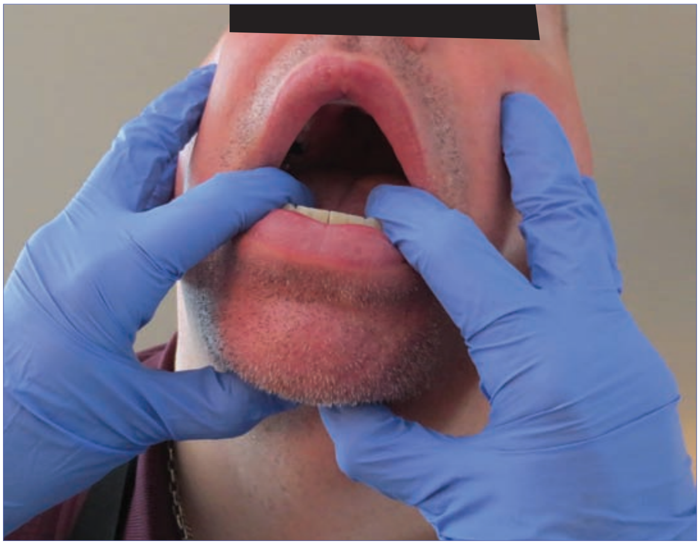


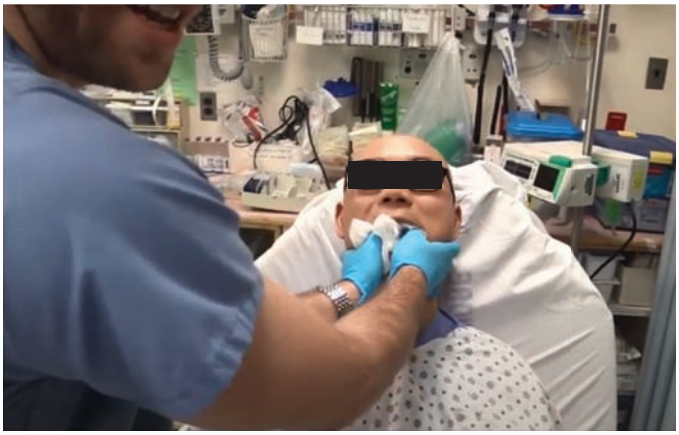
FIGURE 48.7 Photograph showing the wrist-pivot method.

GAG-REFLEX METHOD

- Ensure that patient does not have airway compromise, for example, is not intoxicated or does not have a head injury.
- Stimulate the soft palate gently with a tongue blade to induce a gag reflex.
- Muscles of mastication should relax with gag reflex, allowing reduction of dislocation.

SYRINGE METHOD

- Place a 5- or 10-mL syringe (based on the ability to fit) between the molars on the side of the mandibular dislocation (just one side if bilateral) (**VIDEO 48.2**).
  - The same syringe may be used to lie down between both inferior and superior molars.
- Ask patient to bite down and to roll the syringe back and forth between their teeth until reduction is achieved (**FIGURE 48.8**).
  - The patient is reproducing the same downward and posterior motion/forces one would normally apply using the standard method of closed reduction.
- Move to opposite side and repeat in bilateral dislocation.
- This method has a success rate of 97% with reduction time of less than 1 minute in 77% of cases (Gorchynski, Karabidian, & Sanchez, 2014).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VIDEO 48.2 Syringe method of mandibular reduction also demonstrating conventional method.

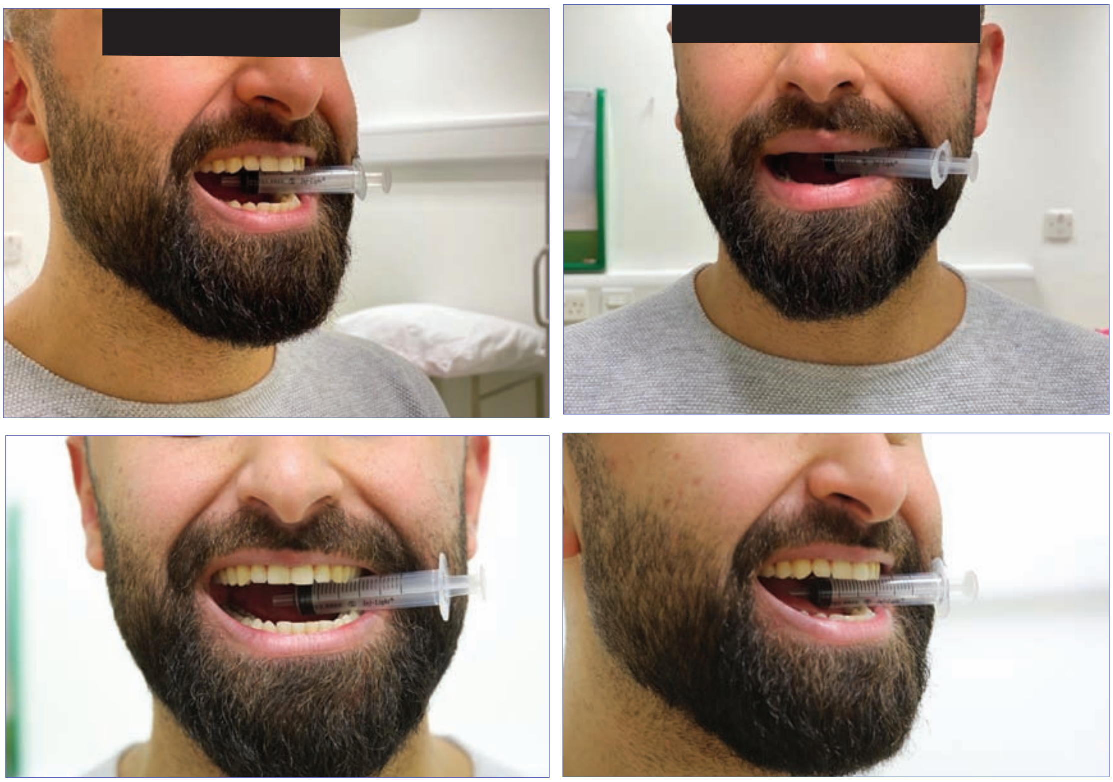
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FIGURE 48.8 Photographs showing the syringe method.

IPSILATERAL METHOD

- Begin this method using the *extraoral approach*.
- Sit patient on a chair with the clinician standing behind the patient.
- Place thumb on the displaced condyle exerting downward pressure while stabilizing the patient's head with the other hand.
- If this fails, proceed to the *intraoral approach*.
- Wrap gloved thumbs in gauze and place on the lower molars on the side opposite to the dislocation.
- Place downward pressure while stabilizing the patient's head with the other hand.
- If this fails, move to the *combined approach*.
- Place thumb over condyle of dislocated side of the mandible while thumb (gloved and covered in gauze) is placed on the lower molars on the opposite side as described earlier.
- Apply downward pressure on both thumbs until reduction is achieved (**FIGURE 48.9**).

UNIFIED-HAND METHOD

- Sit the patient in a chair with their head supported.
- Wrap both gloved thumbs in gauze.
- Place thumbs on the occlusal surface of the lower molars on the dislocated side.
- Exert constant downward and posterior pressure until reduction is achieved (**FIGURE 48.10**).

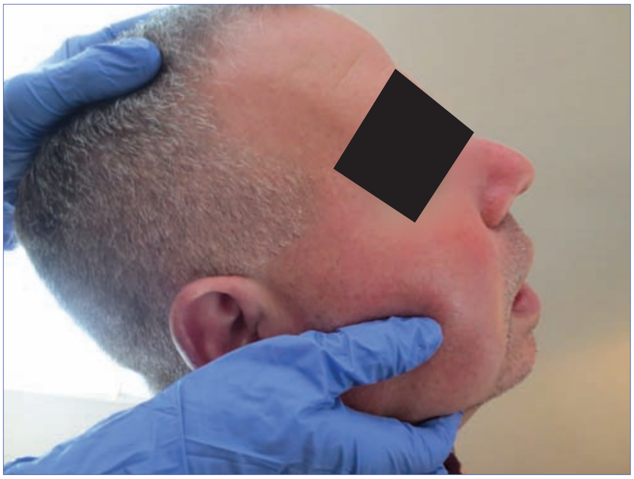

FIGURE 48.9 Ipsilateral method.

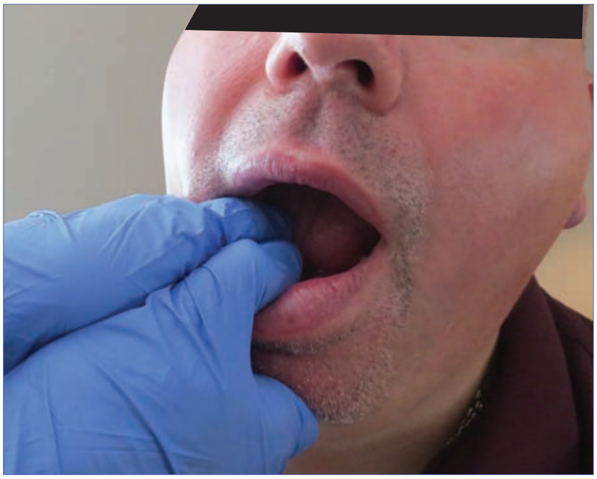

FIGURE 48.10 Unified-hand method.

POSTPROCEDURE CONSIDERATIONS

- Maintain postprocedural sedation observation as per unit policy and procedure.
- Assess for facial nerve injury.
- Advise against extreme mouth opening for 1 week.
- Advise of need for soft, nonchew diet for 1 week.
- Use oral analgesia for pain, for example, nonsteroidal anti-inflammatory medication, acetaminophen.
- Apply cold compress to affected area as required.
- Return in the event of recurrence.

COMPLICATIONS

- Fracture of the mandible
- Facial nerve injury
- Posterior dislocation
- Injury to the external auditory canal
- Bite injury to clinician on reduction of the mandible (intraoral techniques)
- Internal carotid branch injury (rare)
- Complications associated with conscious sedation if used

PEARLS

- Atraumatic dislocations can be reduced in the ambulatory or ED setting.
- Anatomically, the key to reducing a closed mandibular dislocation is to apply downward and posterior forces to the mandible allowing the mandibular condyle in order to pass inferior to the anterior lip of the articular eminence and back into the mandibular fossa.
- Attempt extraoral or syringe technique first as these do not require sedation.
- Traumatic dislocations are usually accompanied by mandibular fractures—these require imaging.
- This is an "across the room" diagnosis.
- In atraumatic and/or recurrent cases, imaging may be avoided.
- Successful reduction usually warrants conscious sedation, as the masseter muscle force is difficult to overcome when it is in a state of spasm.
- Acute dystonia may have a similar presentation.
- Always wrap thumbs with gauze before attempting reduction when utilizing the conventional technique (**FIGURE 48.11**)
- Masseter muscle spasm is associated with much pain and apprehension.
- CT scan of the mandible, while possesing the highest sensitivity of detecting occult fractures, is not routinely needed for the atraumatic (most common) dislocation (**FIGURE 48.12**).

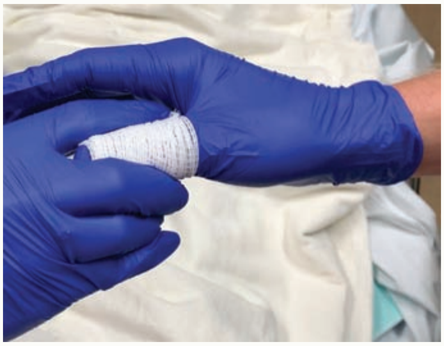

FIGURE 48.11 Have an assistant wrap small gauze around both thumbs in order to mitigate personal injury while using the conditional mandibular reduction technique.

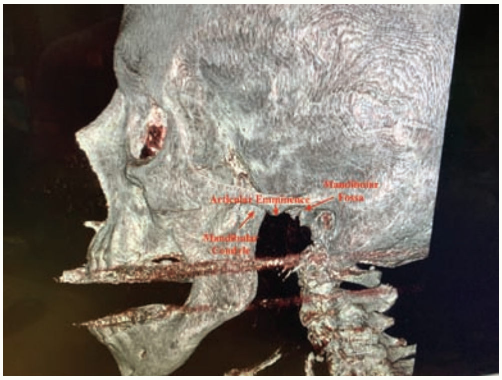

FIGURE 48.12 3-D reconstruction CT scan showing typical mandibular dislocation; note the mandibular condyle is anterior to the articular eminence and any reduction technique must provide downward and posterior forces to negotiate it (mandibular condyle) inferior to the anterior lip of this articular eminence and back into the mandibular fossa.

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UNIT XIV

Procedures for Managing Common Musculoskeletal Conditions and Injuries

CHAPTER

49

Procedures for Arthrocentesis

Allison Zanaboni

BACKGROUND

Evaluation of joint pain from both traumatic and atraumatic causes occurs frequently in the ED. Although physical exam can aid in differentiation of articular versus periarticular pathology, performance of arthrocentesis is frequently necessary to make a definitive diagnosis in acute arthropathy. Joint effusions cause significant pain through distension of the joint capsule and can limit mobility; thus, drainage of a tense effusion or hemarthrosis can provide significant therapeutic benefit as well.

The evaluation of acute arthritis in the acute care setting must include consideration of septic arthritis. The synovium, which is highly vascularized, lacks a basement membrane, making it prone to hematogenous bacterial spread. Joints can also become infected following trauma, from direct inoculation, or from spread of an adjacent infection. Patients with immunocompromise, malignancy, and those with preexisting joint disease are at increased risk of septic arthritis. Although clinicians must maintain septic arthritis in the differential diagnosis for acute monoarticular arthritis, arthrocentesis and joint fluid analysis with culture are required to confirm the diagnosis. Cellulitis, bursitis, tendonitis, Baker's cyst, and deep vein thrombosis must also be considered in the differential diagnosis. Indications for performing arthrocentesis are for the diagnostic evaluation of an acutely painful joint, therapeutic drainage, and for the injection of medication for pain relief (see Chapter 50).

PATIENT PRESENTATION

- Traumatic or atraumatic arthritis, commonly monoarticular
- Joint swelling
- Pain +/−
- Possible overlying warmth or erythema

TREATMENT

The affected joint should be fully exposed and evaluated for signs of overlying skin infection and palpated for effusion and landmark identification. Arthrocentesis is usually approached from the extensor surface of the joint because the extensor surfaces are generally more superficial, expose more of the joint, and the neurovascular structures are commonly embedded along the flexor surface.

Bedside ultrasound can aid in detection of effusions not readily identified on physical exam and can be particularly helpful in evaluation of small effusions and deep joint spaces. Ultrasound has both the advantage of identifying effusions as well as the ability to guide an approach for arthrocentesis, either through the static identification of the appropriate site of needle insertion or through dynamic needle guidance. The ultrasonographic appearance of fluid cannot differentiate between septic effusions and sterile fluid.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

Arthrocentesis should aim to remove as much fluid as possible to optimize diagnostic and therapeutic benefits. The use of the largest needle allowable for the joint will aid in easier aspiration and minimize obstruction of the lumen. For large effusions, a three-way stopcock can be used to allow one to replace the syringe without dislodging the needle from the joint space.

When performing arthrocentesis, it is vital to rule out septic arthritis given the significant morbidity and mortality associated with a missed or delayed diagnosis. Fluid analysis should consist of a Gram stain, cell count, crystal analysis, and culture. A positive Gram stain confirms the diagnosis; however, a negative Gram stain does not rule out septic arthritis. In general, cell counts of more than 50,000 white blood cells (WBCs)/mm^3 warrant treatment for septic arthritis, although certain causative bacteria, such as *Neisseria gonorrhoeae*, may have lower synovial WBC counts. Gout and pseudogout have crystal formation and usually induce less than 50,000 WBCs/mm^3. Rheumatoid arthritis and the seronegative arthritides also usually induce less than 50,000 WBCs/mm^3. Osteoarthritis usually has less than 4,000 WBCs/mm^3.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Cellulitis overlying the site of needle entry
- Bacteremia
  - Bleeding diathesis should generally be corrected.
  - Patients on direct oral anticoagulants and those on warfarin with therapeutic international normalized ratios (INRs) have a very low risk of significant bleeding complicating arthrocentesis.
- Prosthetic Joint
  - Prosthetic joint aspiration should commonly be done only in consultation with orthopedic surgery.

SPECIAL CONSIDERATIONS

Septic Arthritis

Septic arthritis involves a bacterial infection of the joint space. Contamination occurs either via the bloodstream, iatrogenicity, or by local extension; patients with damaged (e.g., patients with rheumatoid arthritis) or prosthetic joints have an increased risk. Patients usually present with an acutely swollen monoarticular painful joint, limited range of motion, and a fever. Suspected infectious arthritis requires prompt arthrocentesis for diagnosis. In addition to the immediate broad-spectrum antibiotic therapy, surgical drainage and debridement are in order. Hematogenous spread is the most common mechanism (abscess, wound infection, sepsis, gonorrhea) followed by direct trauma, including iatrogenic injury.

Risk factors include:

- Prosthetic joint
- Intravenous (IV) drug abuse
- Intraarticular injections
- Joint diseases (especially rheumatoid)
- Diabetes
- Older age
- Chronic skin diseases

Causative organisms:

- *Staphylococcus*
- *Streptococci*
- *S. epidermis*
- *Haemophilus influenza*
- *N. gonorrheae*

Joint in order of involvement:

- Knee
- Hip
- Wrist
- Shoulder
- Ankle

PROCEDURE PREPARATION

- Sterile gloves and drapes
- Antiseptic skin cleanser such as chlorhexidine
- Local anesthetic agent
- 18- to 25-gauge needle
- 10- to 60-mL syringe
- Tubes for lab analysis of synovial fluid for Gram stain, cell count, culture, and crystals
- Ultrasound with sterile ultrasound probe cover and sterile gel, if applicable

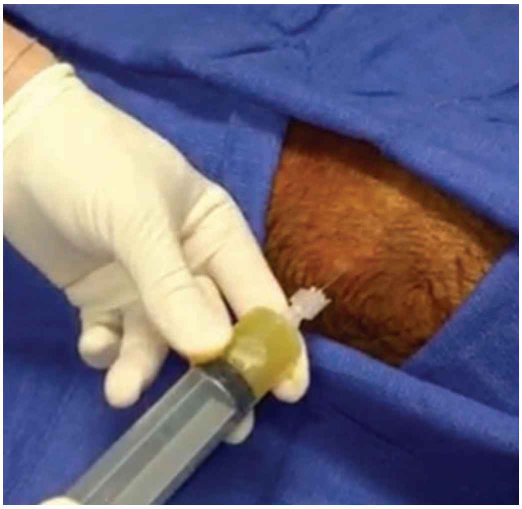


FIGURE 49.1 Knee arthrocentesis.

PROCEDURE

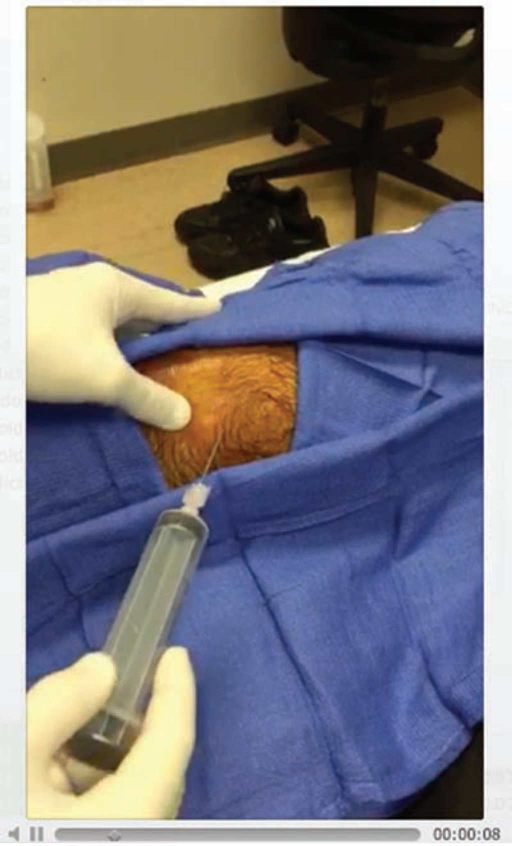
General Technique

- Sterile technique is mandatory and aseptic technique is paramount to avoid introduction of infection into the joint space.
- *Approach joint from the extensor surface*
    - Joint capsule is more superficial on extensor side
    - Avoids neurovascular structures
- Inject local anesthetic along the anticipated needle path down to the level of the joint capsule.
- Ultrasound can aid in identifying small or deep effusions; a static or dynamic technique can guide fluid aspiration.
    - Prevention of unnecessary arthrocentesis is possible through confirmation of the effusion with point-of-care ultrasound (POCUS).
    - Procedural success is increased and potential damage to important structures (vessels, tendons, ligaments, and cartilage) is minimized with visualization of the needle tip.

Procedure by Site

KNEE JOINT

- Position patient seated or supine with knee extended or in 15 degrees of flexion.
    - Place a folded towel under the knee to help achieve this angle.
- Identify the region of the midpatella on the medial aspect of the knee.
- Using an 18-gauge needle, insert approximately 1 cm medial and slightly cephalic to the midpatella, angling just posterior to the patella, toward the intercondylar femoral notch (**FIGURE 49.1** and **VIDEO 49.1**).
    - Keep the needle parallel to the floor.



VIDEO 49.1 Knee joint arthrocentesis, medial approach. Note the importance of keeping the needle parallel to the floor and slightly cephalad toward the intercondylar notch.

- Using the same landmarks and technique, a lateral approach may be utilized but from the lateral side.
- Ultrasound-assisted knee arthrocentesis (**FIGURE 49.2**):
    - Bookman and Pereira (2014) have shown that POCUS-guided injections were significantly more accurate than blind injections in clinical studies of the knee joint (92.7% vs. 77.9%).
    - Use a high-frequency linear transducer in a longitudinal orientation over the quadriceps tendon at the point where it inserts on the patella (**FIGURE 49.2A**).
    - A joint effusion will be seen as dark fluid deep to the quadriceps tendon between the anterior and posterior suprapatellar bursa fat pads that extend under the patella (**see FIGURES 49.2B** and **49.2C**).
    - Once an effusion is diagnosed, the probe can be moved medially or laterally to determine the largest pocket of synovial fluid. The needle can be inserted with static guidance or dynamically (**VIDEO 49.2**).

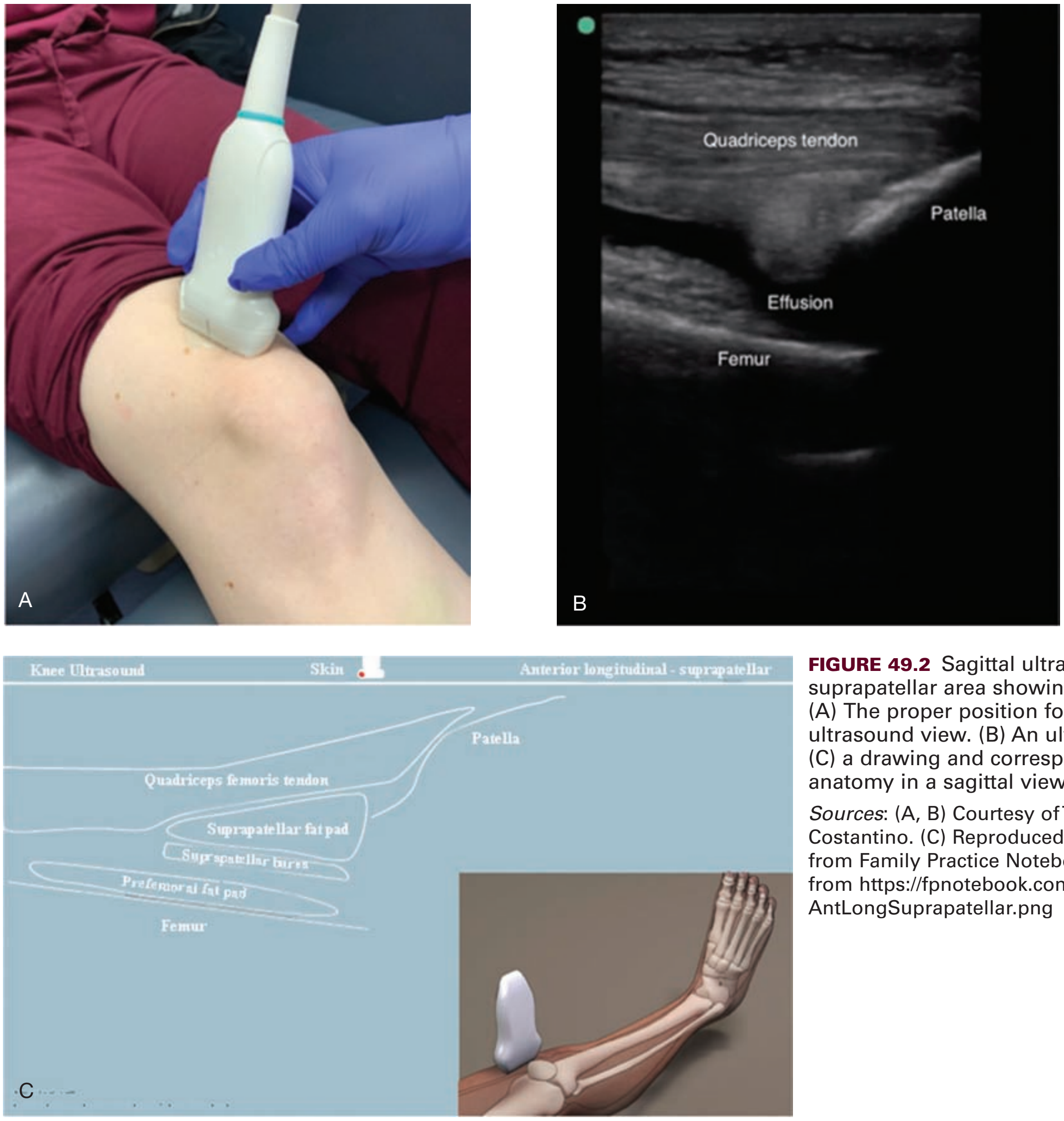
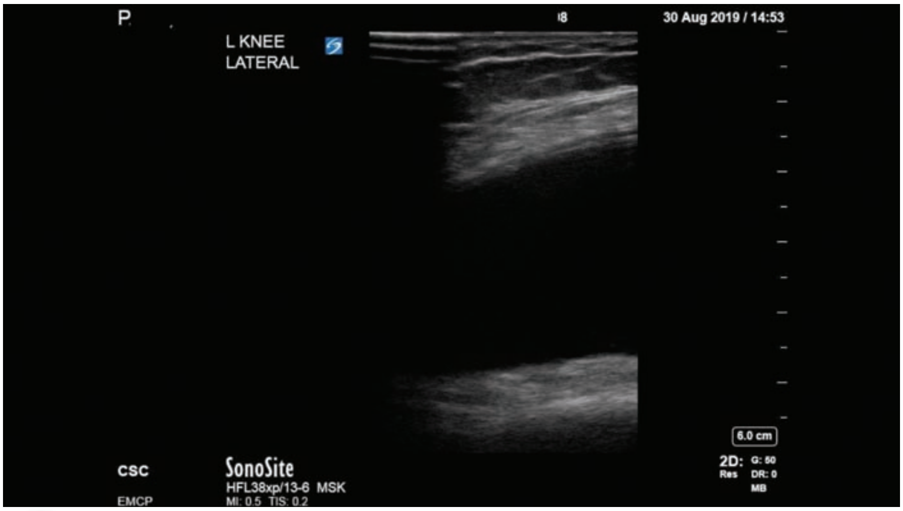

A
B
Quadriceps tendon
Patella
Effusion
Femur
Knee Ultrasound
Skin
Anterior longitudinal - suprapatellar
Patella
Quadriceps femoris tendon
Suprapatellar fat pad
Suprapatellar bursa
Prefemoral fat pad
Femur
C

FIGURE 49.2 Sagittal ultrasound in the suprapatellar area showing joint effusion. (A) The proper position for a sagittal ultrasound view. (B) An ultrasound image and (C) a drawing and corresponding image with anatomy in a sagittal view.

Sources: (A, B) Courtesy of Thomas G. Costantino. (C) Reproduced with permission from Family Practice Notebook. Retrieved from https://fpnotebook.com/_media/usKnee_AntLongSuprapatellar.png


P
L KNEE
LATERAL
30 Aug 2019 / 14:53
6.0 cm
CSC
EMCP
SonoSite
HFL38xp/13-6 MSK
MI: 0.5 TIS: 0.2
2D: G: 60
Res DR: 0
MB

VIDEO 49.2 POCUS-guided arthrocentesis.

GLENOHUMERAL JOINT (SHOULDER)

- Position patient seated upright with hands in a neutral position on the lap with the palms up.
- Identify the junction of the coracoid process medially and the humeral head laterally.
- Using a 20- or 22-gauge needle, insert inferolateral to the coracoid, in the sulcus bordered by the coracoid and the humeral head, aiming posteriorly (**FIGURE 49.3**).

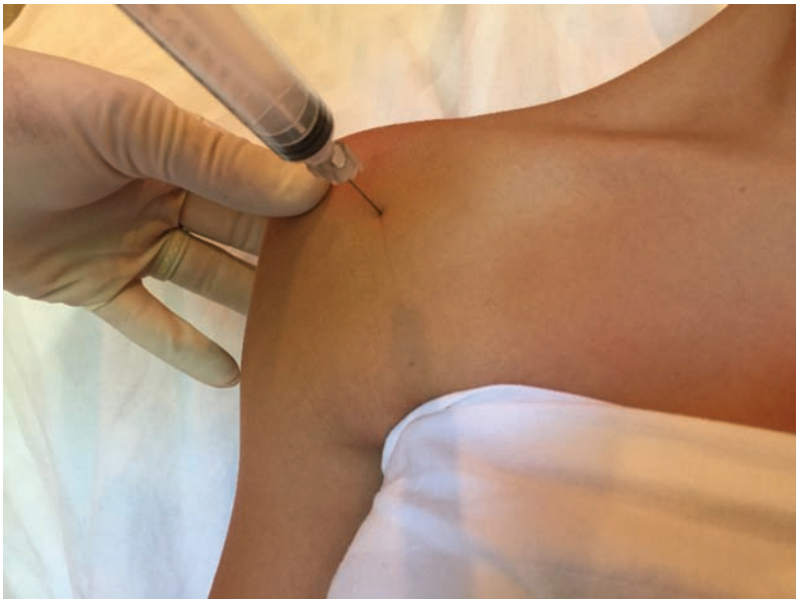


FIGURE 49.3 Glenohumeral arthrocentesis.

- Ultrasound-assisted shoulder arthrocentesis:
    - Use a high-frequency linear transducer or lower frequency curved-array probe if needed for depth.
    - For an anterior approach, place the probe transversely over the region of the biceps groove of the humerus looking for fluid collecting around the biceps tendon in this region, which communicates with the joint space (**FIGURE 49.4**).
    - With ultrasound guidance, the posterior approach accessing the posterior glenohumeral recess is preferred (**FIGURE 49.5**).
        - In their systemic review, Daley et al. (2011) have shown that the use of such imaging improved injection accuracy in the glenohumeral joint from 79% to 95%.
    - Have the patient grasp their contralateral shoulder with the hand on the affected side. Place the probe over the scapular spine and follow it laterally to identify the articulation of the glenoid with the humeral head. This is the region where an effusion would be visualized.

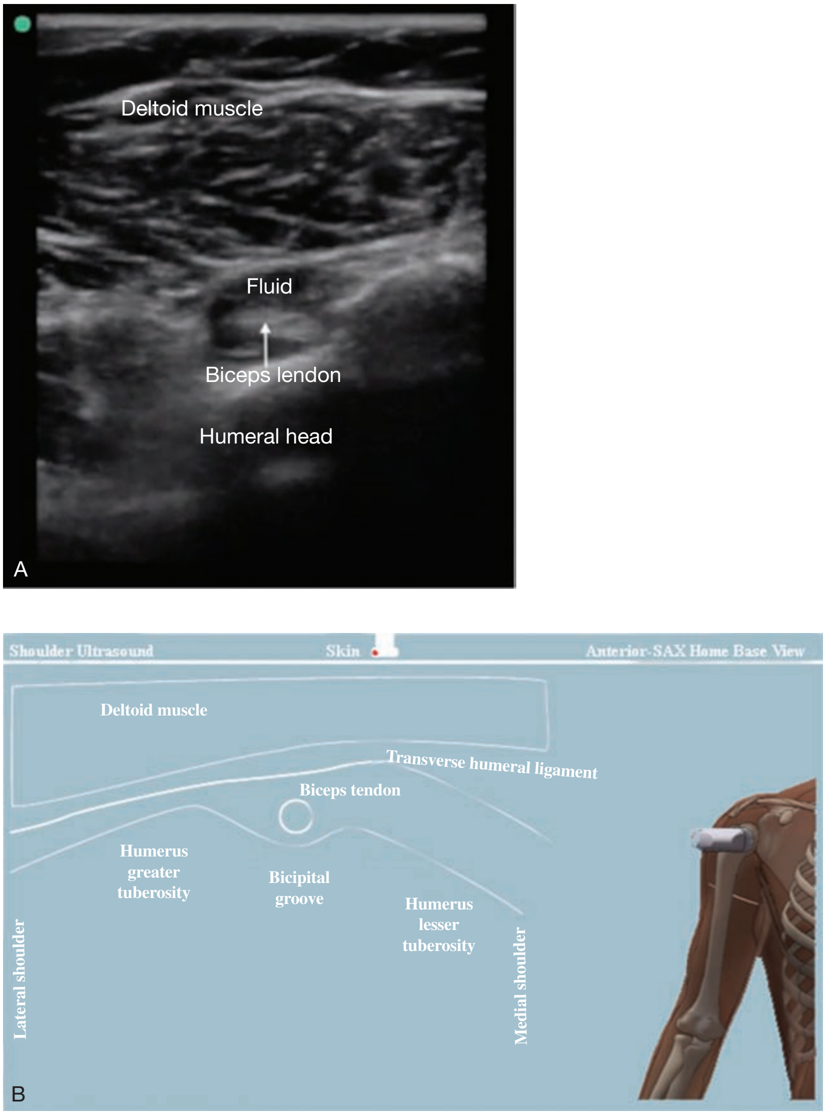

Deltoid muscle
Fluid
Biceps tendon
Humeral head
A
Shoulder Ultrasound
Skin
Anterior-SAX Home Base View
Deltoid muscle
Transverse humeral ligament
Biceps tendon
Humerus greater tuberosity
Bicipital groove
Humerus lesser tuberosity
Lateral shoulder
Medial shoulder
B

FIGURE 49.4 Transverse ultrasound of anterior glenohumeral joint. (A) In the ultrasound image, note key landmark of the biceps tendon and the fluid around it. (B) Drawing outlining structures visualized on the ultrasound.

Sources: (A) Courtesy of Thomas G. Costantino. (B) Reproduced with permission from Family Practice Notebook. Retrieved from https://fpnotebook.com/_media/usShoulder_AntSaxHome.png

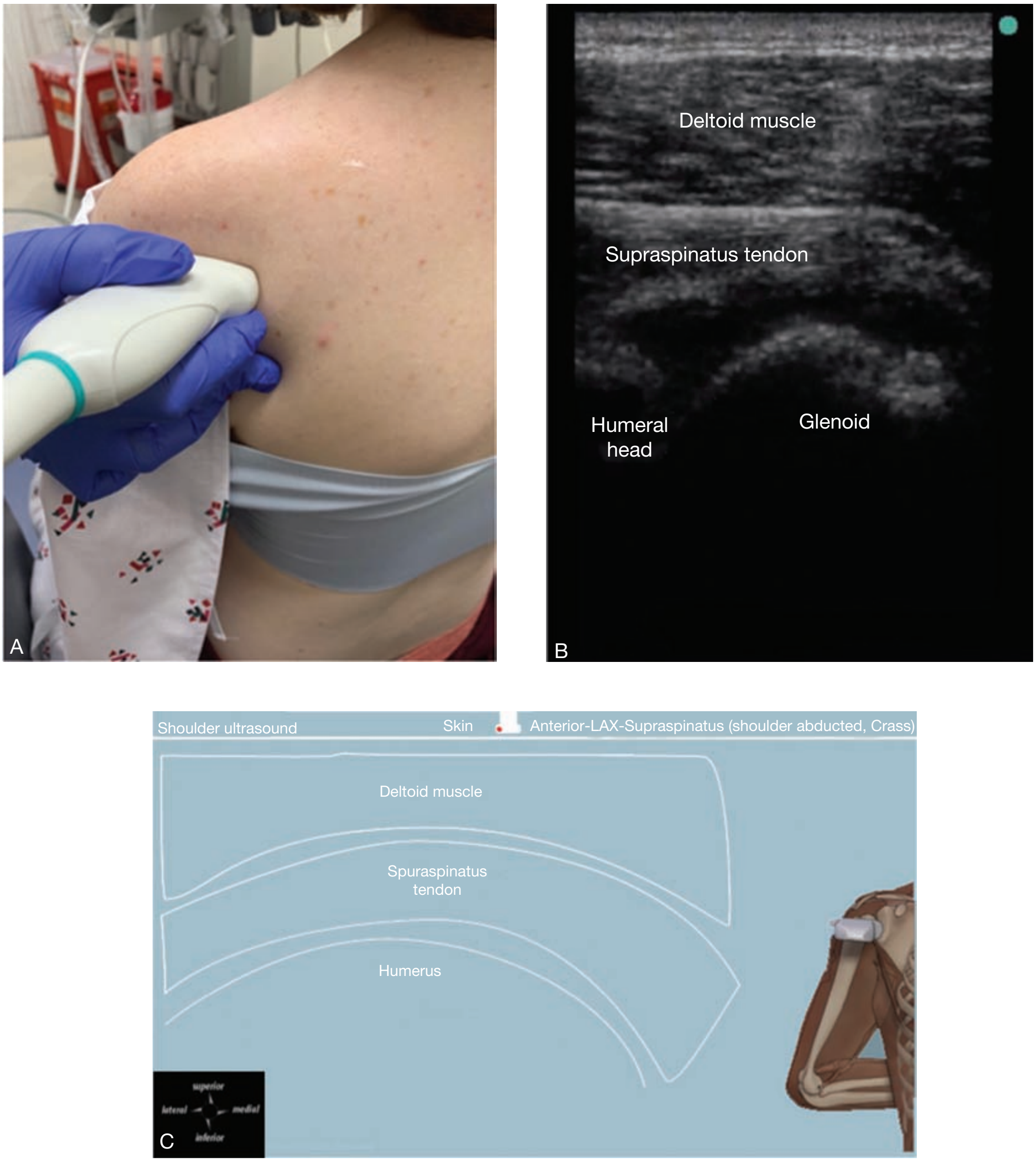

A
Deltoid muscle
Supraspinatus tendon
Humeral head
Glenoid
B
Shoulder ultrasound
Skin
Anterior-LAX-Supraspinatus (shoulder abducted, Crass)
Deltoid muscle
Spuraspinatus tendon
Humerus
superior
lateral
medial
inferior
C

FIGURE 49.5 Transverse ultrasound of the posterior glenohumeral joint. Note joint effusion. It helps to place the probe slightly medial at first and just under the scapular spine and then move parallel and inferior to the scapular spine laterally until the glenohumeral joint is identified. (A) The proper placement of the ultrasound probe. (B) Ultrasound and (C) diagram of the imaged anatomy.

Sources: (A, B) Courtesy of Thomas G. Costantino. (C) Reproduced with permission from Family Practice Notebook. Retrieved from https://fpnotebook.com/_media/usShoulder_AntLaxSupraspinatus.png

RADIOHUMERAL JOINT (ELBOW)

- Position patient seated, the arm slightly abducted, elbow flexed to 90 degrees, and the forearm pronated.
- Identify the lateral epicondyle of the humerus and the radial head.
    - If there is difficulty identifying this space with the elbow flexed, extend the elbow to identify the articulation of the radius and humerus and then flex to 90 degrees.

- Using a 22-gauge needle, enter the joint laterally, perpendicular to the joint (**FIGURE 49.6**).
- Ultrasound-assisted elbow arthrocentesis (**FIGURE 49.7**):
  - Use a high-frequency linear transducer in a longitudinal orientation over triceps tendon where it inserts on the olecranon process of the ulna.
  - A joint effusion will be seen as fluid within the olecranon fossa and will elevate the posterior fat pad.
  - The needle can be placed parallel to the ultrasound and advanced into the joint between the triceps tendon and lateral epicondyle.

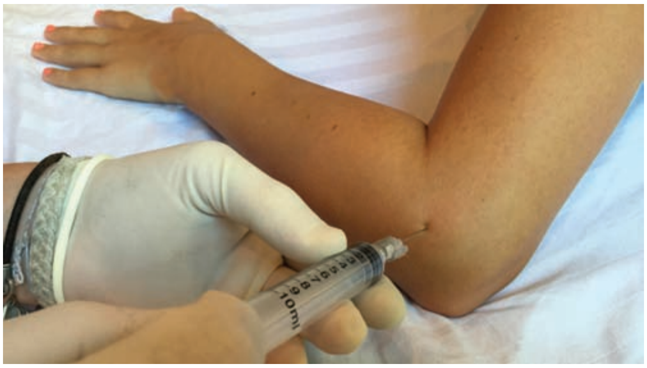
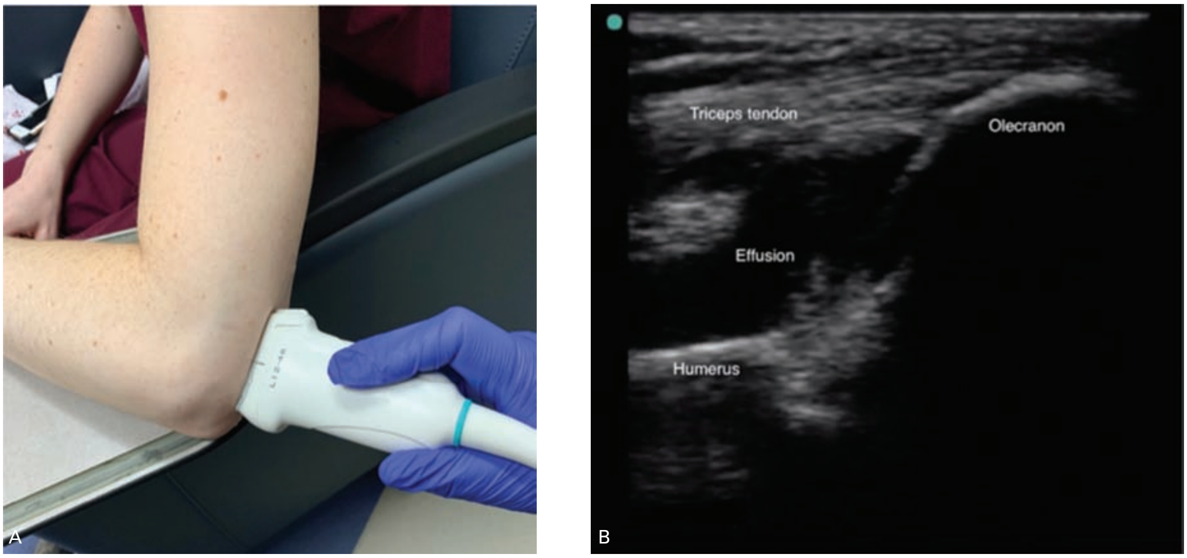


FIGURE 49.6 Radiohumeral arthrocentesis.


A
Triceps tendon
Olecranon
Effusion
Humerus
B

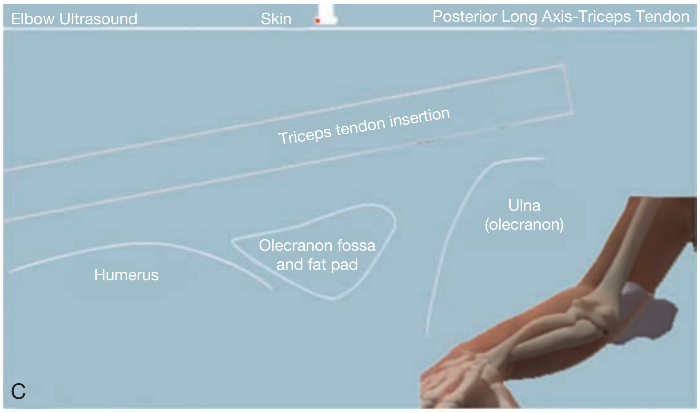

Elbow Ultrasound
Skin
Posterior Long Axis-Triceps Tendon
Triceps tendon insertion
Ulna
(olecranon)
Olecranon fossa
and fat pad
Humerus
C

FIGURE 49.7 Posterior longitudinal ultrasound of the olecranon fossa. Note joint effusion and displacement of fat pad. (A) Proper placement of the ultrasound probe. (B) Ultrasound and (C) diagram of the imaged anatomy.

Sources: (A, B) Courtesy of Thomas G. Costantino. (C) Reproduced with permission from Family Practice Notebook. Retrieved from https://fpnotebook.com/_media/usElbow_PostMidLongTricepsInsert.png

TIBIOTALAR JOINT (ANKLE)

- Position patient supine on the bed with the foot in plantar flexion.
- Identify the medial malleolar sulcus between the medial malleolus medially and the anterior tibial tendon laterally.
- Using a 20- or 22-gauge needle, insert into the midpoint of the medial malleolar sulcus, aiming posteriorly, and advance about 2 to 3 cm to reach the joint space (**FIGURE 49.8**).
- Ultrasound-assisted ankle arthrocentesis (**FIGURE 49.9**):
    - Use a high-frequency linear transducer in a longitudinal orientation over the distal tibia and slide distally to visualize the junction of the tibia and the talus.
    - A joint effusion will be seen as triangular fluid collection in this space.
    - The needle can be guided into the effusion in plane approaching from the distal end of the probe.

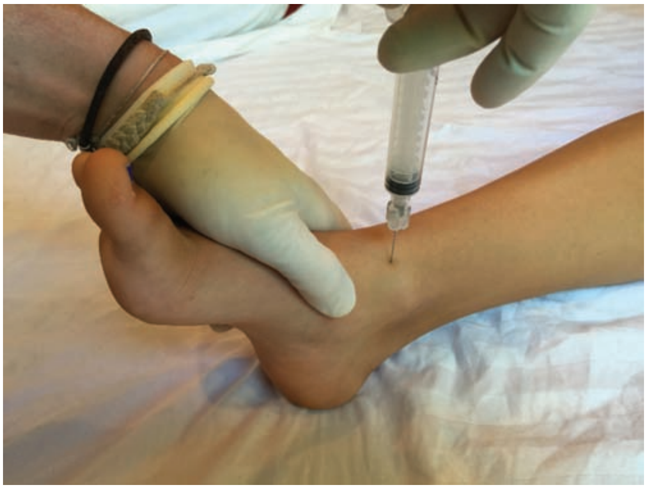


FIGURE 49.8 Tibiotalar arthrocentesis.

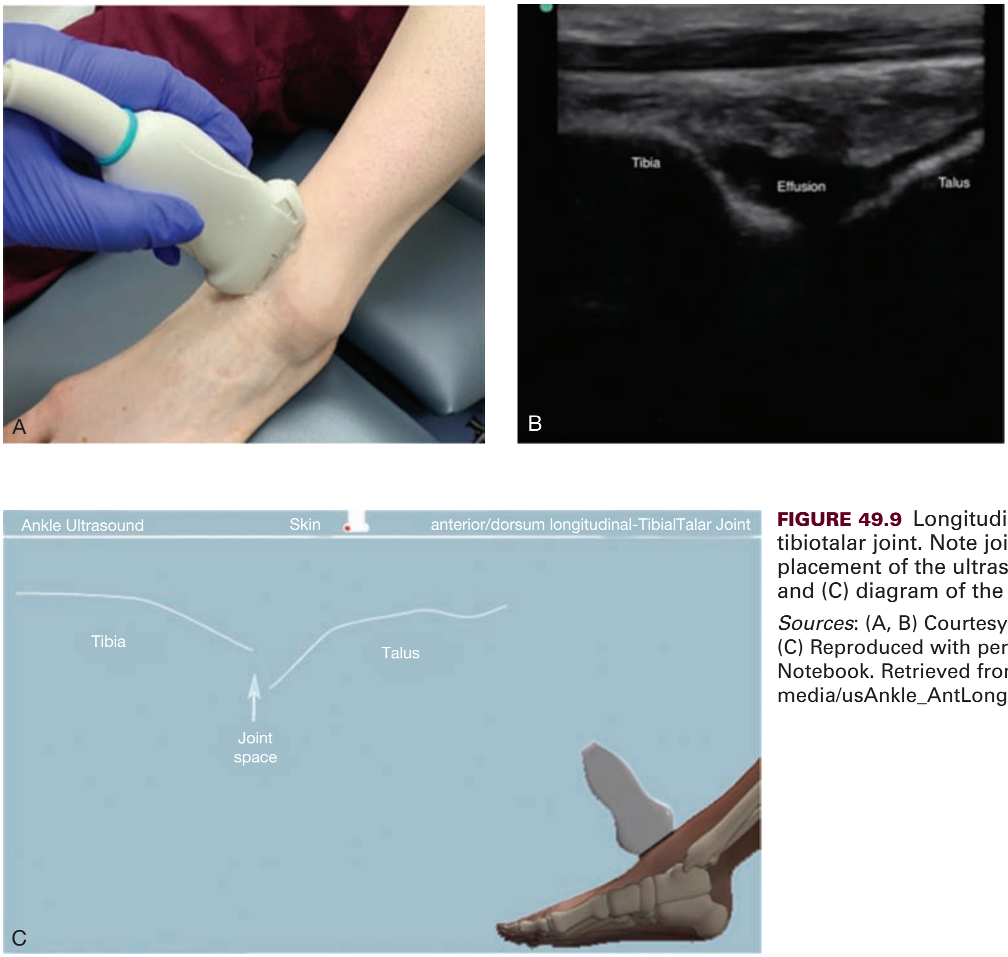


FIGURE 49.9 Longitudinal ultrasound of the tibiotalar joint. Note joint effusion. (A) Proper placement of the ultrasound probe. (B) Ultrasound and (C) diagram of the imaged anatomy.

Sources: (A, B) Courtesy of Thomas G. Costantino. (C) Reproduced with permission from Family Practice Notebook. Retrieved from https://fpnotebook.com/_media/usAnkle_AntLongTibialTalarJoint.png

RADIOCARPAL JOINT (WRIST)

- Position patient seated, forearm pronated, and wrist flexed 20 to 30 degrees with ulnar deviation.
  - Apply traction distally to further open the joint space.
- Identify the prominence at the center of the dorsal distal radius (Lister's tubercle) and the extensor pollicis longus tendon, which runs radial to this tubercle.
- Using a 22-gauge needle, insert distal to the radial tubercle on the ulnar side of the extensor pollicis longus tendon, where a sulcus can be palpated perpendicular to the skin (**FIGURE 49.10**).
- Ultrasound-assisted wrist arthrocentesis (**FIGURE 49.11**):
  - Use a high-frequency linear transducer in a longitudinal orientation over the distal radius at its articulation with the lunate or scaphoid.
  - Apply traction distally to further open the joint space.
  - An effusion will be seen extending from the space to above the carpal bone.
  - The needle can be guided into the effusion in plane from the distal end of the probe.

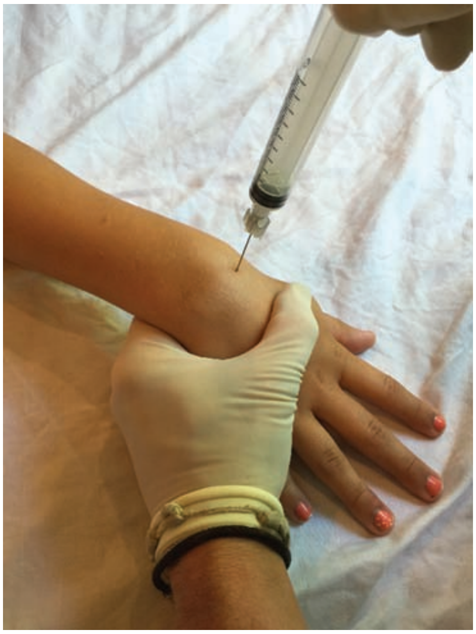
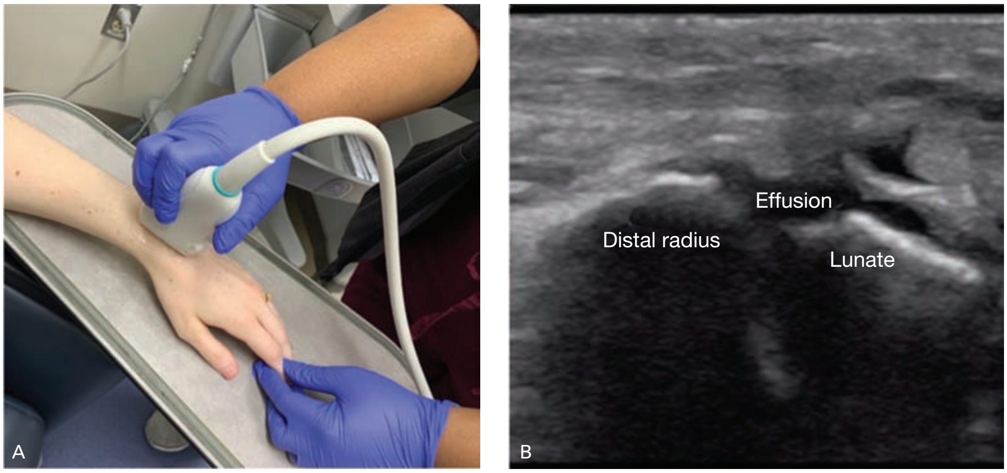


FIGURE 49.10 Radiocarpal arthrocentesis.



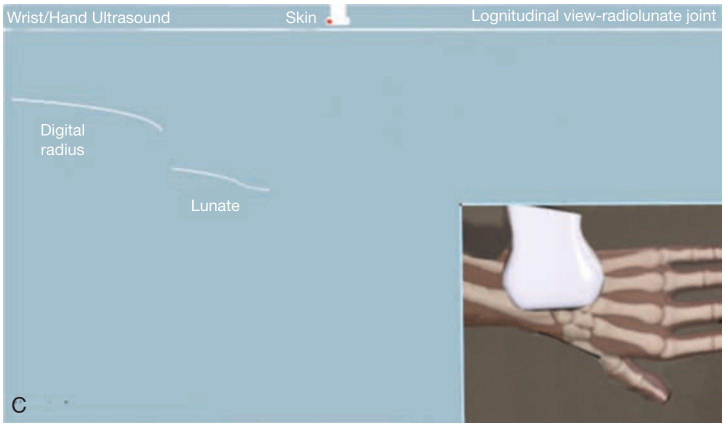


FIGURE 49.11 Longitudinal dorsal ultrasound of the radiolunate joint. Note effusion. (A) Proper placement of the ultrasound probe. (B) Ultrasound and (C) diagram of the imaged anatomy.

Source: (B) Courtesy of Thomas G. Costantino. (C) Reproduced with permission from Family Practice Notebook. Retrieved from https://fpnotebook.com/ortho/wrist/

INTERPHALANGEAL AND METACARPOPHALANGEAL/ METATARSOPHALANGEAL JOINTS

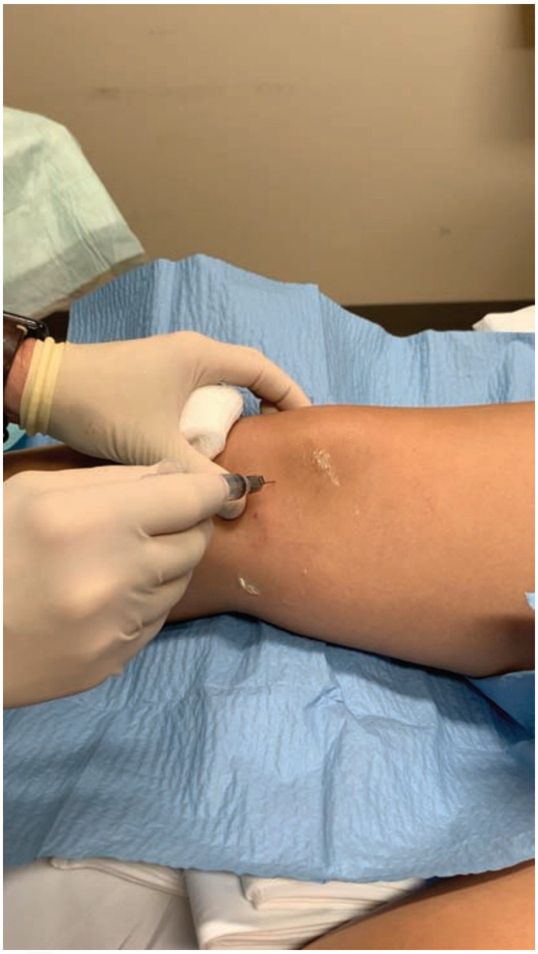
- Position patient with hand or foot flat and digit of interest flexed.
  - Apply traction distally to further open the joint space.
- Identify the bony prominences on either side of the joint being evaluated, as well as the midline where the extensor tendon runs.
  - For the first carpometacarpal joint, identify the abductor pollicis longus by having the patient oppose the thumb.
- Using a 22- or 25-gauge needle, insert from the dorsal surface just medial or lateral to the extensor tendon at or between the palpated prominences.
  - For the first carpometacarpal joint, insert on the radial side of the abductor pollicis longus.

POSTPROCEDURE CONSIDERATIONS

- Apply a clean bandage to the area.
- Reassessment of range of motion and ligamentous stability should be improved after removal of synovial fluid.
- Fluid samples should be sent promptly to the lab for analysis.

EDUCATIONAL POINTS

- A dry joint tap is rare and, if it occurs, the position of the needle should be questioned; one should at least aspirate minimal physiologic synovial fluid (**VIDEO 49.3**).
- Viscosity of synovial fluid can be assessed by dripping a small amount of fluid from the syringe needle and measuring the length of the string created (**FIGURE 49.12**). Normal synovial fluid will have a string length of 4 to 6 cm, whereas inflammatory fluid will have reduced viscosity secondary to the action of hyaluronidase on hyaluronic acid in the synovial fluid.
- When only a small amount of fluid is obtained, synovial fluid culture should be prioritized over other fluid analyses.
- The evaluation of acute arthritis in the acute care setting must include consideration of septic arthritis.
- The synovium, which is highly vascularized, lacks a basement membrane, making it prone to hematogenous bacterial spread.
- Approach all joints from the extensor surface joint capsule as it is more superficial on the extensor surface and avoids neurovascular structures, which are on the deeper flexor side; also the extensor surface has fewer tendons and ligaments than the flexor surface.
- The needle should always go around and not through any tendons.
- Try to avoid piercing the articular cartilage, which is avascular and therefore may not heal.
- Do not bounce the needle off the bone as this hurts!
- Try to place the joint in slight flexion in order to maximize the size of the joint cavity.
- Apply distal in-line traction to the small joints of the wrists, hands, and feet to enlarge the joint cavity, as this allows the joint capsule to widen.



VIDEO 49.3 Minimal synovial return signifies one is in the joint and probably not reflective of a pathologic condition. A "dry" tap signifies that the needle is probably not in the joint.

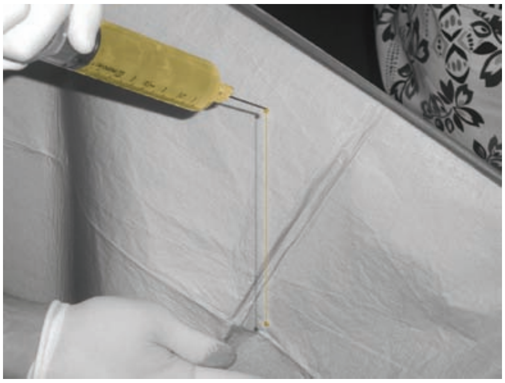


FIGURE 49.12 String sign.

COMPLICATIONS

- Infection
- Hemarthrosis
- Corticosteroid-related complications

PEARLS

- A swollen and painful joint is septic arthritis until proven otherwise. Articular disease causes diffuse joint capsule distension and leads to painful, limited range of motion in all directions with both active and passive range of motion; periarticular conditions are associated with more localized pain with relatively painless passive range of motion.
- Ultrasound guidance can help detect effusions in deep or small joint spaces and when physical exam is limited by range of motion restrictions or habitus.
- Comparison to the contralateral joint can be helpful when there is doubt about a possible effusion, particularly when using ultrasound.
- Arthrocentesis of the acute traumatic hemarthrosis not only provides symptomatic relief of pain, but also allows for a better exam and proper assessment of ligament stability.
- If performing arthrocentesis on a traumatically injured joint, examine the fluid obtained for fat globules, which are diagnostic of an intraarticular fracture; fat globules in the synovial fluid are diagnostic of a fracture.
- Worsening pain, swelling, and redness within a day or 2 of corticosteroid injection is consistent with steroid flare from the precipitation of crystals out of the steroid preparation.
- Because of the action of hyaluronidase on hyaluronic acid, viscosity can be tested by dripping a small amount of fluid from the syringe needle and measuring the length of the string created. In inflammatory conditions, especially in infectious etiologies, the “string sign” will be much less than 10 cm.
- A dry tap is rare and, if it occurs, one should question the proper position of the needle.
- If minimal fluid returns, synovial culture trumps other lab tests.

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CHAPTER 50

Procedures for Therapeutic Joint Injection

Saloni Malik, Kraftin E. Schreyer, and Keith Lafferty

BACKGROUND

Therapeutic joint injection for joint pain has been used since the 1950s. Injured joint tissue leads to a proliferation of the inflammatory cascade, both from the synovial cells themselves and from circulating polymorphonuclear leukocytes. This proliferation of cytokines increases blood flow to the joint, induces pain and swelling, and decreases range of motion. Injection of corticosteroids suppresses this inflammatory cascade by decreasing capillary permeability and by attenuating many of the cytokine effects. Therapeutic joint injections are most commonly performed in the shoulder, elbow, wrist, knee, and ankle joints. The approach may be identified either using anatomical landmarks, or more preferably via ultrasound (US) guidance as per recent literature (Daniels, Cole, Jacobs, & Phillips, 2018). In a meta-analysis, Berkoff, Miller, and Block (2012) have shown that US guidance versus use of anatomical landmarks resulted in an accuracy of 96% versus 78% in the knee and 97% versus 65% in the shoulder joint. Likewise, Ruiz, Bravo, Duarte, Adler, and Raya (2019) have shown that the success rate using US-guided intraarticular knee injection was 89% compared to 58% using the landmark method.

Relief of symptoms is expected to take effect within 1 to 3 days, and may last for 2 to 4 weeks, with some studies showing benefit up to 24 weeks after injection. Due to the risk of loss of cartilage volume and bone density from chronic steroid exposure, therapeutic joint injections should not be performed serially for a prolonged period of time.

PATIENT PRESENTATION

- Pain
- Tenderness
- Swelling
- Erythema
- Decreased range of motion

TREATMENT

Steroid injections are used to treat several different types of painful arthritic conditions, including osteoarthritis, inflammatory crystalline arthritis, rheumatoid arthritis, tendinopathies, and autoimmune arthritis, but it should be noted that there is a lack of strong data showing long-term clinical benefit for many of these etiologies. In fact, ***recent literature suggests that there are risks of worsening disease progression with long-term repeated steroid injections for arthritic joints***. Administration of this treatment should be done only after a discussion of risks and benefits with the patient, and an understanding of the long-term management strategy of their underlying condition. ***Therapeutic joint injection should never be used as treatment for septic arthritis***.

The typical agent used in therapeutic joint injection is a corticosteroid. Ideally, the corticosteroid used should:

- Have long duration of action
- Produce the least possible postinjection pain
- Possess minimal side effects

The duration of the effect is related to the solubility of the agent, with lower solubility corticosteroids having an increased duration of effect in the joint and minimal systemic absorption. However, the low-solubility agents are prepared in crystalline solution, which may produce greater postinjection pain than the higher solubility agents. There are some who suggest using an intermediate solubility compound to mitigate the shortcomings of either high- or low-solubility options. There are no large, randomized trials directly comparing the efficacy and side effect profiles of these agents; the selection of a particular agent is most often based on considerations that include cost, availability, and versatility of the agent. **TABLE 50.1** summarizes the properties and recommended volumes for some common corticosteroid agents.

The use of local anesthetic, such as lidocaine, in combination with a steroid may also have clinical benefit, although this too has not been definitively established in the literature. ***The rationale for dilution with local anesthetic includes immediate pain relief during the procedure, decreased postinjection pain, and possibly reduced side effects from the steroid injections***. The disadvantages of using anesthetic include the small risk of contamination from multidose vials and the theoretical risk of flocculation when glucocorticoid and local anesthetic are mixed. The increased volume of solution to be injected may also increase intraarticular pressure and pain if too much is used.

Other injectable agents include hyaluronic acid derivatives and platelet-rich plasma solutions. These agents are not currently recommended as part of acute routine care due to lack of evidence demonstrating clinical benefit.

TABLE 50.1 Summary of Treatment for Therapeutic Joint Infection

Medication	Large Joint (mg)	Small Joint (mg)	Potency	Solubility	Duration
Hydrocortisone acetate (Hydrocortone)	NA	NA	1	High	Low
Triamcinolone acetonide (Kenalog)	20	2–6	5	Intermediate	Intermediate
Triamcinolone hexacetonide (Aristospan)	20	2–6	5	Intermediate	Intermediate
Methylprednisolone acetate (Depo-Medrol)	40	3.5–0.5	5	Intermediate	Intermediate
Betamethasone acetate/sodium phosphate (Celestone Soluspan)	6	1.5–3	25	Low	High
Dexamethasone acetate (Decadron-LA)	5	0.5–1.5	25	Low	High

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Infection of either articular or overlying periarticular tissue
- Acute fractures
- Prosthetic joints
- Bleeding diatheses
- Bacteremia
- Chronic debilitating diseases such as tuberculosis
- Tendinopathies
- Plan for arthoplasty within 3 months
- Two previous injections of the affected joint with treatment failure

PROCEDURE PREPARATION

- Sterile gloves
- Sterile drapes
- Skin cleanser with chlorhexidine or providone-iodine
- Local anesthetic agent in a 3-mL syringe and 27-gauge needle
- Injection solution in a 5- to 10-mL syringe, and 18- to 22-gauge needle, depending on joint size
- Sterile technique is mandatory and aseptic technique is paramount (**FIGURE 50.1**)

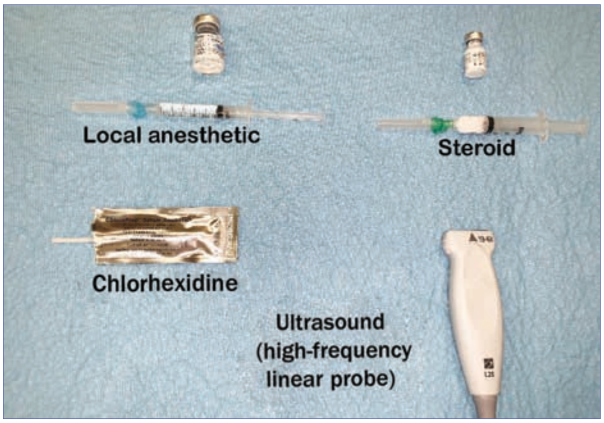


FIGURE 50.1 Photograph of procedure preparation equipment.

PROCEDURE

Prepare a sterile field, isolating the joint that will be injected. Prepare a solution of the steroid injection agent, diluting with local anesthetic if desired. Clean the skin. Using US guidance, preferably over anatomical landmarks, identify the approach and entry point to the joint. Use a small quantity of local anesthetic to raise a wheal in the skin at the point of entry. Insert the steroid-filled syringe into the joint space through the numbed area of skin, and inject the desired volume of solution. Withdraw the needle and cover with gauze.

On occasion, a therapeutic joint injection immediately follows an arthrocentesis. In this situation, an angiocatheter may be used and left in place after the arthrocentesis. The corticosteroid-filled syringe can now be attached to the angiocatheter and injection procedures may be followed. As an alternative, the needle can be left in the joint and the syringe containing the steroid injection switched with one containing the joint aspirate.

Knee: Landmark Approach

- Position towels under the knee to give 15 degrees of slight flexion.
- For the medial approach, identify the medial midpatellar area; the site of entry should be just below this.
- Direct a 20-gauge needle slightly cephalad toward the intercondylar femoral notch (**FIGURE 50.2**).
- Keep the needle just under the posterior surface of the patella.
- Make sure the needle stays parallel to the floor.
- A lateral approach may be used as well.

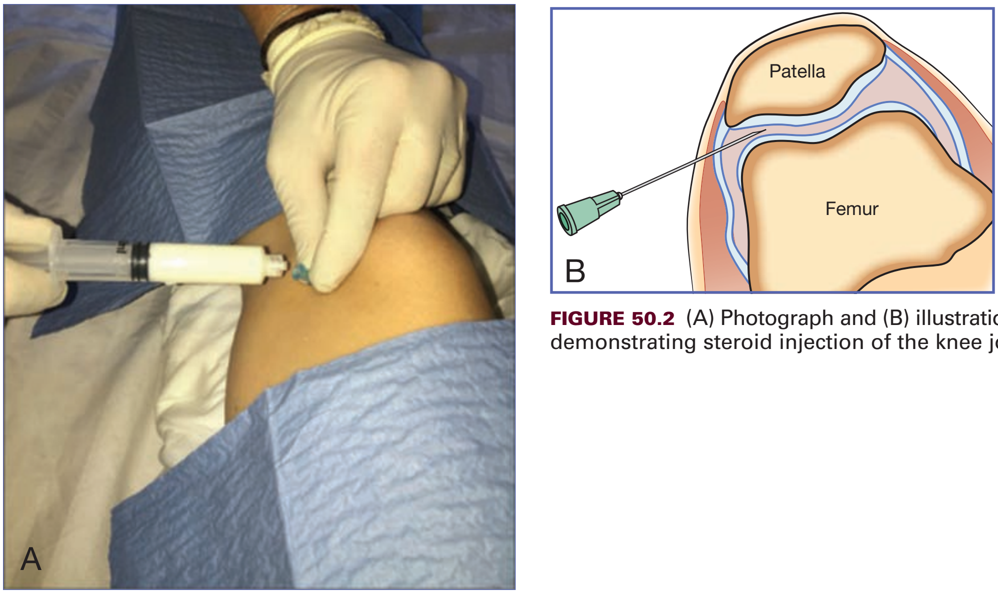


FIGURE 50.2 (A) Photograph and (B) illustration demonstrating steroid injection of the knee joint.

Knee: US-Guided Approach

- Hold the US probe in transverse position superior to the knee, between the distal femur and patella (**FIGURE 50.3**).
- Direct the needle toward the joint space as indicated by the arrow (**FIGURE 50.4**).

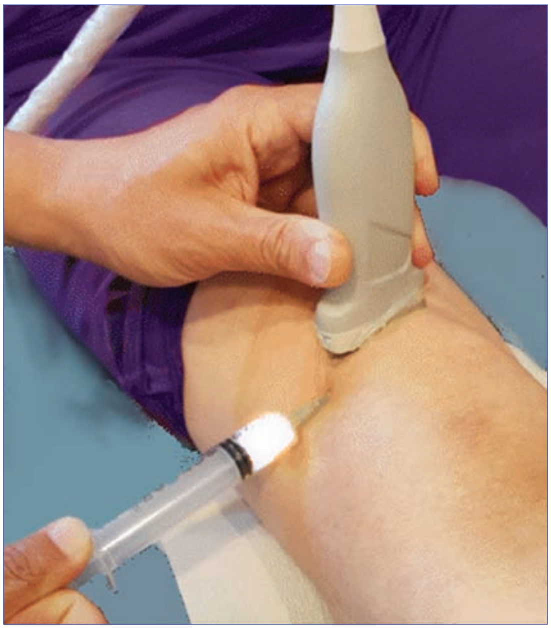


FIGURE 50.3 Photograph showing ultrasound-guided injection of the knee joint.

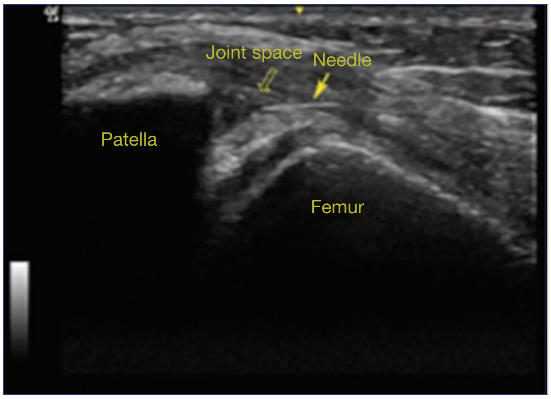


FIGURE 50.4 Ultrasound image of the knee joint.

Radiohumeral Joint (Elbow): Landmark Approach

- Patient should be sitting upright in bed.
- Elbow should be flexed at 90 degrees on the table with the forearm in pronation.
- Identify the lateral epicondyle and the head of the radius.
- Using a 22-gauge needle, enter the joint in a medial manner, perpendicular to the joint (**FIGURE 50.5**).

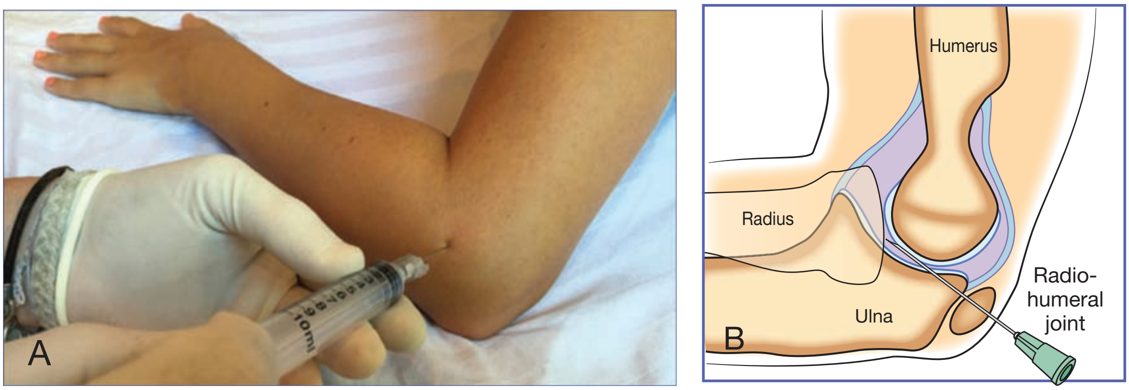


FIGURE 50.5 (A) Photograph and (B) illustration of steroid injection of the elbow joint.

Radiohumeral Joint (Elbow): US-Guided Approach

- Hold the US probe in longitudinal position medial to the lateral epicondyle (**FIGURE 50.6**).
- Direct the needle toward the joint space as indicated by the arrow (**FIGURE 50.7**).

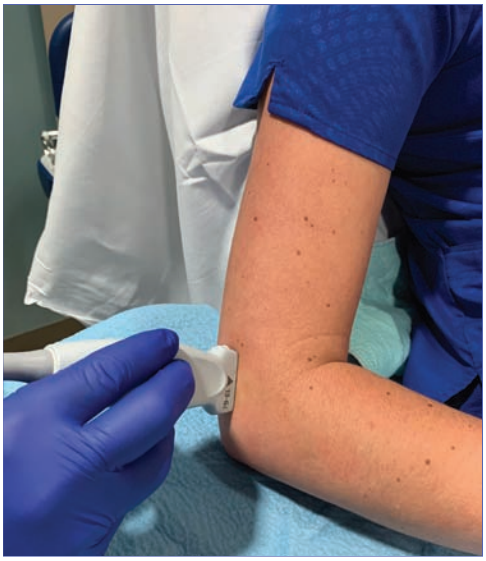


FIGURE 50.6 Photograph showing ultrasound-guided injection of the elbow joint. Note the elbow should be in 90 degrees flexion.

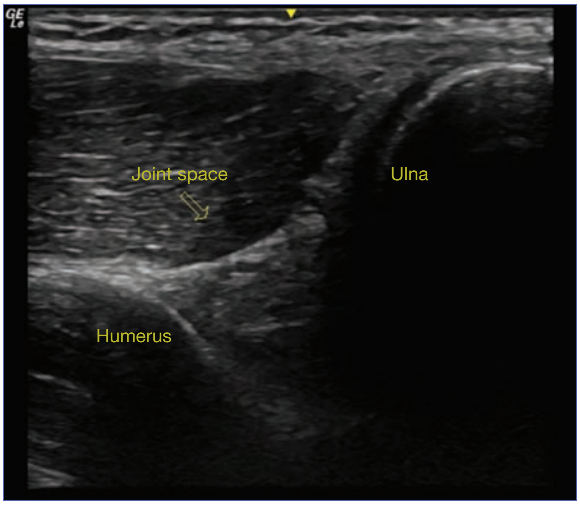


FIGURE 50.7 Ultrasound image of the elbow joint.

Radiocarpal Joint (Wrist): Landmark Approach

- Patient should be sitting upright in bed.
- Forearm/wrist is prone on the table with the wrist flexed at 30 degrees with slight traction.
- Identify the dorsal radial tubercle (it is a prominence of the distal dorsal radius).
- The extensor pollicis longus tendon runs radial to this tubercle and also makes the dorsal tendon border of the snuff box.
- Enter the joint space with a 22-gauge needle distal to the radial tubercle and on the ulna side of the extensor pollicis longus tendon, where a sulcus can be palpated perpendicular to the skin (**FIGURE 50.8**).

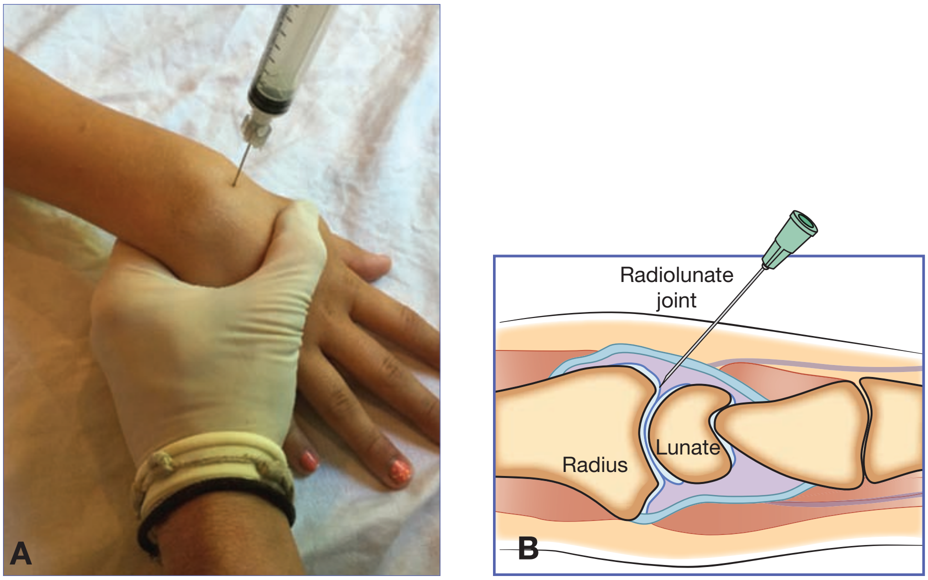


FIGURE 50.8 (A) Photograph of steroid injection of the wrist joint. (B) Shown in the illustration is the radiolunate joint.

Radiocarpal Joint (Wrist): US-Guided Approach

- Hold the US probe in longitudinal position medial to the radial tubercle epicondyle (**FIGURE 50.9**).
- Direct the needle toward the joint space as indicated by the arrow (**FIGURE 50.10**).

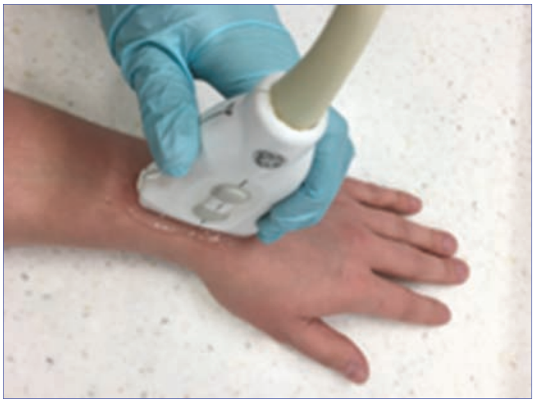
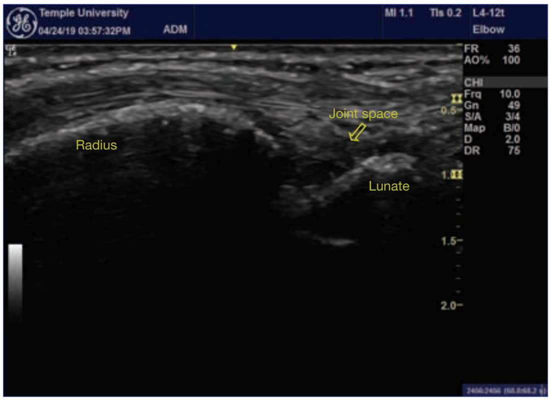


FIGURE 50.9 Photograph demonstrating ultrasound-guided injection of the wrist joint.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Elbow
FR 36
AO% 100
CHI
Frq 10.0
Gn 49
S/A 3/4
Map B/0
D 2.0
DR 75
Joint space
Radius
Lunate
0.5
1.0
1.5
2.0

FIGURE 50.10 Ultrasound image of the wrist joint.

Tibiotalar Joint (Ankle): Landmark Approach

- Patient should be supine on the bed.
- Foot is in plantar flexion.
- Identify the medial malleolar sulcus (lateral to the medial malleolus).
- The lateral margin of the sulcus is bordered by the anterior tibial tendon (best seen by active dorsiflexion).
- Insert a 20- or 22-gauge needle dorsally (perpendicular to the fibular shaft) into the medial malleolar sulcus (**FIGURE 50.11**).

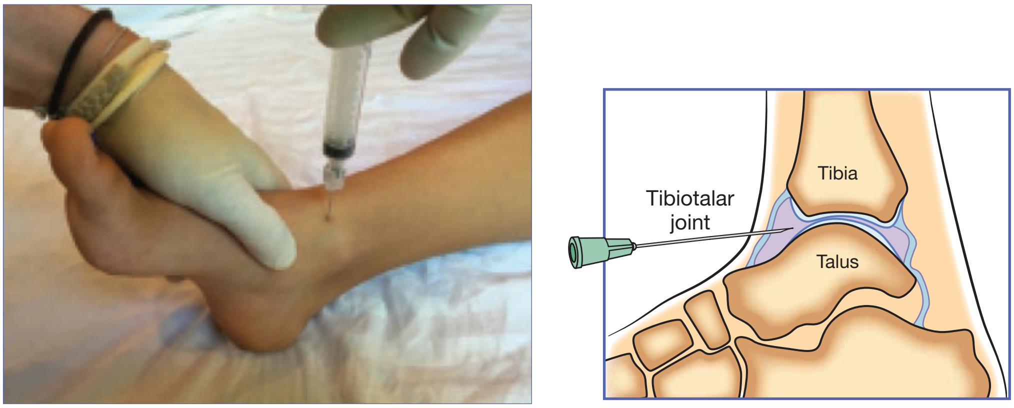

Tibia
Tibiotalar joint
Talus

FIGURE 50.11 Photograph and illustration depicting steroid injection of the ankle joint.

Tibiotalar Joint (Ankle): US-Guided Approach

- Hold the US probe in longitudinal position over the medial malleolar sulcus (**FIGURE 50.12**).
- Direct the needle toward the joint space as indicated by the arrow (**FIGURE 50.13**).

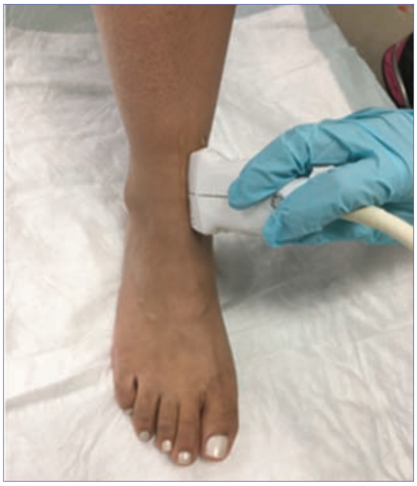
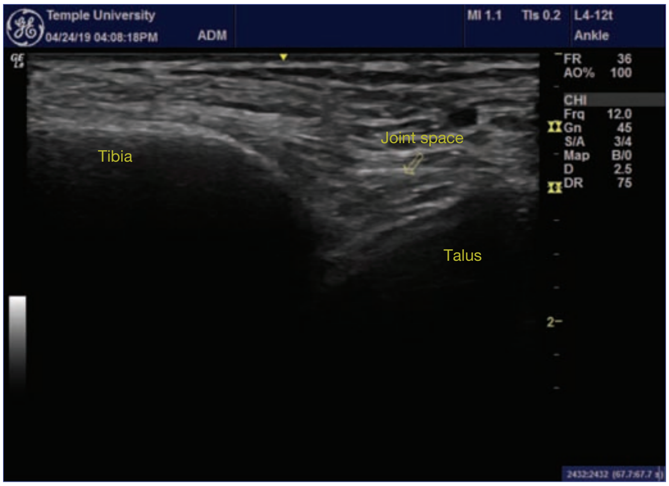


FIGURE 50.12 Photograph depicting ultrasound-guided injection of the ankle joint.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ADM
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Ankle
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AO% 100
CHI
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Gn 45
S/A 3/4
Map B/0
D 2.5
DR 75
Tibia
Joint space
Talus
2

FIGURE 50.13 Ultrasound image of the ankle joint.

Glenohumeral Joint (Shoulder): Landmark Approach

- Patient should be sitting on a stretcher with hands on their lap.
- Identify the coracoid process medially and the humeral head laterally.
- Insert a 20- or 22-gauge needle in the sulcus bordered by the coracoid and the humeral head.
- Insert the needle inferiorly and laterally to the coracoid and directed posteriorly (**FIGURE 50.14**).

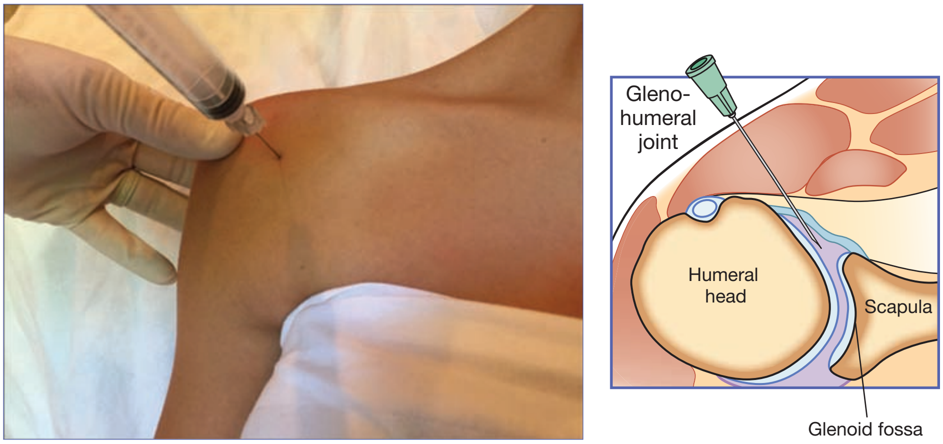
Gleno-humeral joint
Humeral head
Scapula
Glenoid fossa

FIGURE 50.14 Photograph and illustration showing steroid injection of the shoulder joint.

Glenohumeral Joint (Shoulder): US-Guided Approach

- Using a posterior approach, hold the US probe in transverse position inferior to the acromion and parallel to the spine of the scapula (**FIGURE 50.15**).
- Direct the needle toward the joint space as indicated by the arrow (**FIGURE 50.16**).

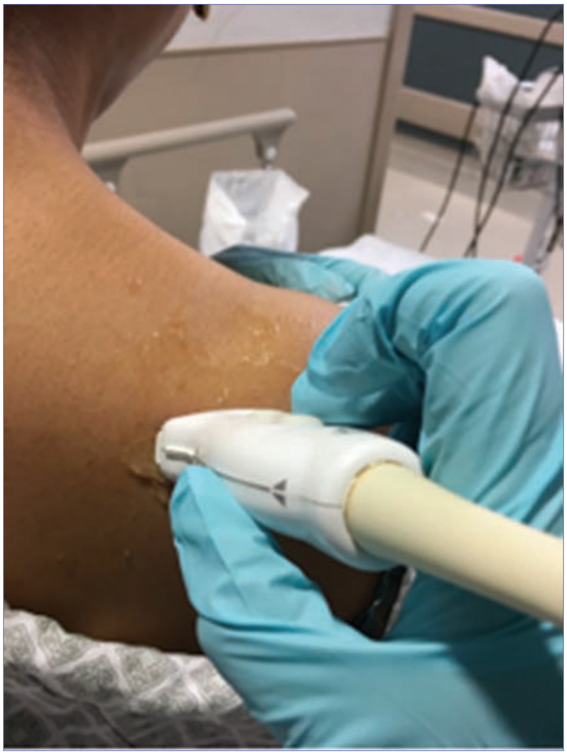

FIGURE 50.15 Photograph of ultrasound-guided injection of the shoulder joint.

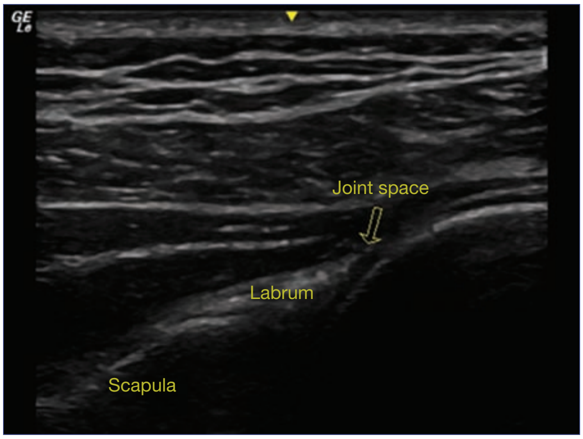

FIGURE 50.16 Ultrasound image of the shoulder joint.

POSTPROCEDURE CONSIDERATIONS

Hold pressure to prevent bleeding.

EDUCATIONAL POINTS

- US-guided arthrocentesis reduces procedural pain, improves arthrocentesis success rates, leads to greater synovial fluid yield with more complete joint decompression, and improves clinical outcomes.
- US is significantly less expensive than other soft-tissue imaging modalities such as MRI; also length of patient stay is substantially decreased.
- US guidance notably improves injection accuracy in the target intraarticular joint injection of all structures, including the knee.
- The enhanced injection accuracy achieved with US needle guidance directly improves patient-reported clinical outcomes and cost-effectiveness.

COMPLICATIONS

Complications of therapeutic joint injection include the possibility of infection, bleeding, and pain. The risk of infection is substantially greater in the setting of septic arthritis, or any articular or periarticular infection; thus, therapeutic joint injection should not be pursued in those clinical scenarios.

The most immediate complication of therapeutic joint injection is a transient postinjection flare, when the injected corticosteroid agent itself initially causes local irritation and inflammation to the joint before its anti-inflammatory biochemical properties take effect, which may take several days.

Due to the potential of corticosteroids to potentially worsen bone density, weaken capsule and ligaments, and inhibit bone healing, repeated injections should be limited. Studies have shown that patients who receive serial corticosteroid injections for longer than 2 years have significantly greater cartilage volume loss. Repeated corticosteroid injections may also cause subcutaneous atrophy and calcification, tendon rupture, and bone necrosis.

PEARLS

- If there is any suspicion of septic arthritis, abandon this treatment.
- The corticosteroid injection may be diluted with local anesthetic such as lidocaine.
- US guidance has been shown to improve intraarticular needle position, and hence improves the outcome.
- Limit injections to a span of 3 months apart, for no more than 2 years.

RESOURCES

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CHAPTER

51

Procedures for Shoulder Dislocation

Matthew Berger, Megan Healy, and Keith Lafferty

BACKGROUND

Because the glenohumeral joint has the most mobile articulation in the body, it also is ***the*** most commonly dislocated joint. In fact, it is responsible for 50% of all major joint dislocations presented to EDs. Its integrity is maintained by the (**FIGURE 51.1**):

- Glenohumeral joint capsule
- Cartilaginous glenoid labrum (which extends the shallow glenoid fossa)
- Muscles of the rotator cuff

Contributing to this propensity for a luxation (synonymous with dislocation as opposed to a subluxation, which describes a partial dislocation) is a:

- Robust range of motion
- Innately loose capsule
- Shallow glenoid fossa
- Lack of anterior muscular support
- Relatively thin anterior–inferior glenohumeral ligament (joint capsule) prone to tears

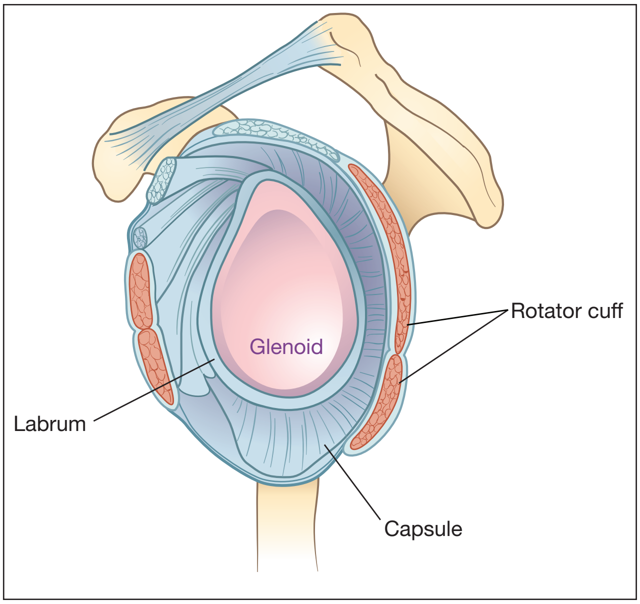

FIGURE 51.1 Anatomical illustration of the glenoid labrum. Note the shallow glenohumeral joint gives way to robust movement and hence needed support must be provided by the joint capsule, labrum (extends the glenoid cavity), and rotator cuff muscles. Any violation of these stabilizing structures lends susceptibility to joint weakening.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

Shoulder dislocations are broadly divided into anterior and posterior types based on the position of the humeral head in relation to the glenoid fossa. Normal anatomy of the shoulder is illustrated in **FIGURE 51.2**. Note that posterior dislocations occur 2% of the time and as such are only briefly discussed here. Anterior dislocations (**FIGURE 51.3**) are subdivided into:

- Subcoracoid (most common)
- *Subglenoid (together, subcoracoid and subglenoid represent 99% of all anterior dislocations)
- Subclavicular
- Intrathoracic

*Rare, and clinically obvious in its unique presentation, an inferior lie of the humeral head may present with the ipsilateral arm in a cephalad position, known as *luxatio erecta* (**see FIGURE 51.7B**).

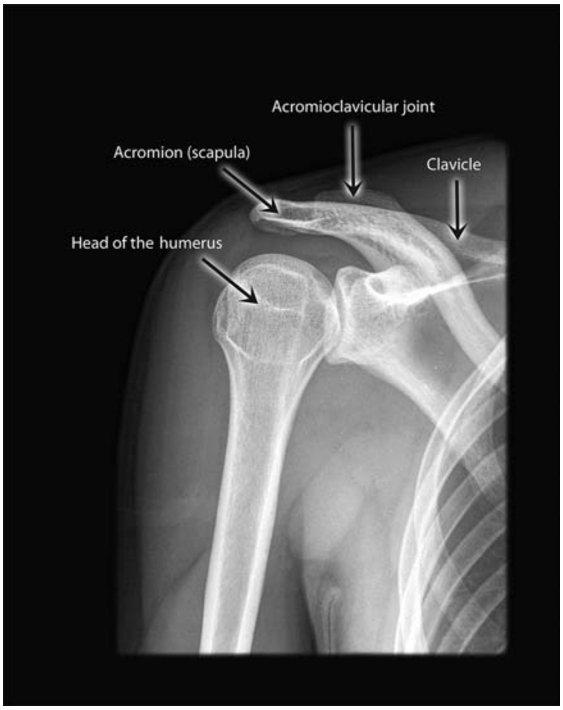

FIGURE 51.2 X-ray of a normal shoulder joint.

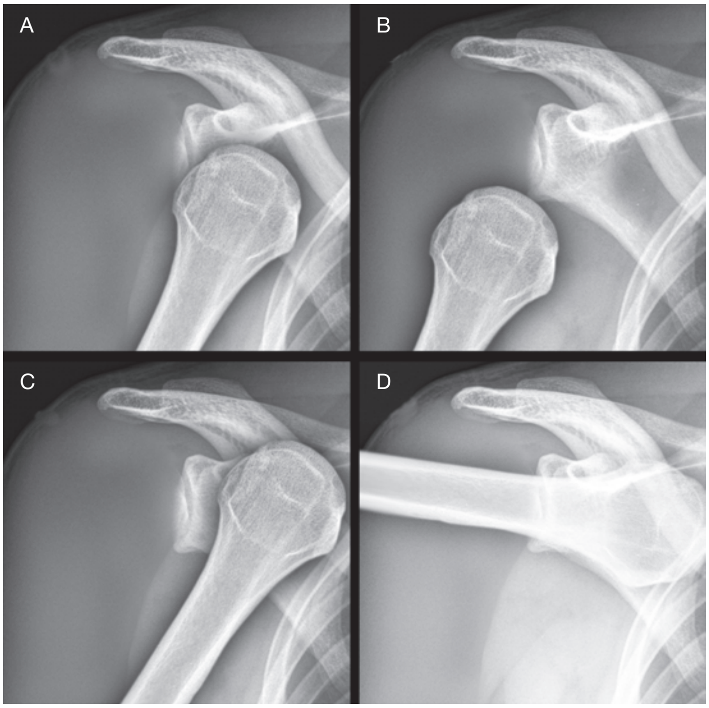

FIGURE 51.3 X-rays showing the types of anterior shoulder dislocation. (A) subcoracoid, (B) subglenoid, (C) subclavicular, (D) intrathoracic (rare).

Anterior Dislocation

- Represents 98% of all glenohumeral dislocations.
- The mechanism of injury in anterior types is usually an indirect force of abduction, extension, and external rotation.
- Rarely, it is the result of a direct blow to the shoulder.
- In general, sporting activity in the young and falling in the elderly are the culprits.
- Recurrence rate is directly related to age, which in turn is directly related to the integrity of various parts of the joint supporting structures.
  - Age less than 20 years—87% recurrence
    - Pathology is likely a Bankart lesion with associated inferior glenohumeral ligament injury.
  - 20 to 40 years—37% recurrence
    - Pathology is likely a disruption of the labral attachment of the glenohumeral ligaments.
  - Age greater than 40 years—5% recurrence
    - Pathology is likely a rotator cuff tear.
- Studies have shown an increase in the incidence of anterior–inferior glenohumeral ligament avulsions from the glenoid rim, now thought to be the primary factor for recurrent dislocations; it is amenable to arthroscopic surgical repair.
  - In fact, the current evidence suggests that younger athletic patients who are unwilling to modify their activities may benefit from stabilization after their initial dislocation to avoid recurrent instability.

  - Rotator cuff injuries are much more common and are reported in up to 30% of those who are older than 40 years of age (as opposed to those patients younger than 30 years of age), as these tendons weaken as one ages.
- Axillary nerve injury secondary to traction neuropraxia is the most common neuronal injury (40% rate) and must be tested for in the pre- and postreduction period (**FIGURE 51.4**).
  - Nerve function almost always returns to normal within time.
- Although there is a proximity to the axillary artery, disruption is extremely rare and usually due to excess force upon delayed closed reductions, but usually it is clinically obvious in terms of anatomy (**FIGURE 51.5**):
  - Coolness
  - Severe persistent pain
  - Axillae hematoma/chest-wall hematoma formation
- This rare event usually occurs in older persons and warrants immediate arteriography.

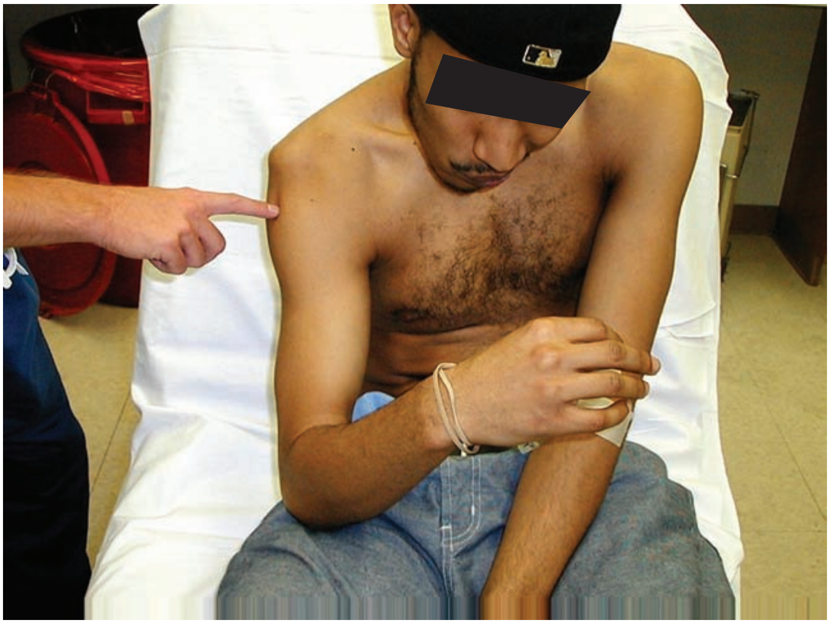

FIGURE 51.4 Testing of the axillary nerve. Apply light touch over the "regimental badge" area as shown.

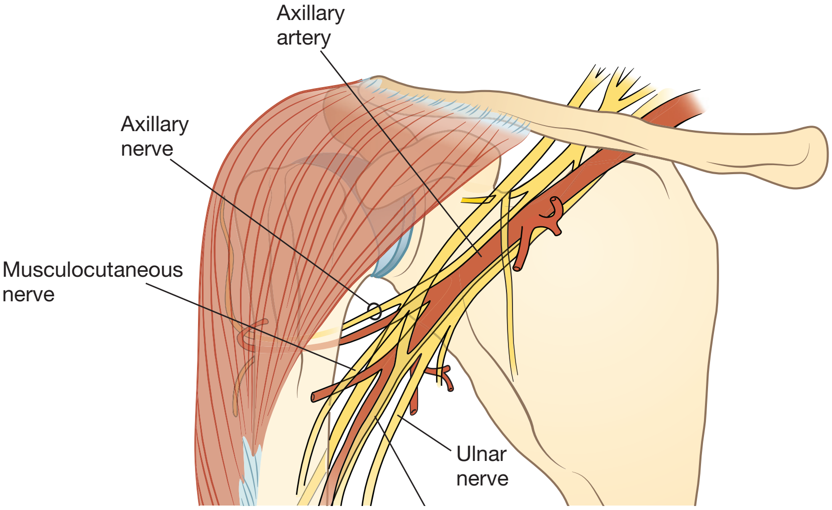

FIGURE 51.5 Illustration depicting shoulder anatomy as it relates to shoulder dislocation. One must test for the integrity of the axillary nerve pre- and postreduction via deltoid function (postreduction) and cutaneous sensation over the deltoid (prereduction). Also note that all glenohumeral dislocations are associated with at least some degree of joint capsule violation.

Posterior Dislocation

- The mechanism is that of an internal rotation and adduction from an indirect force such as a seizure or electrical/lightning shock/strike.
- Posterior dislocations represent 2% of all glenohumeral dislocations.
- Note these forces are opposite to those inducing an anterior dislocation.
- Rarely is direct blunt trauma to the anterior shoulder the culprit.
- These posterior types are often clinically missed because they are sometimes quite subtle on anterior–posterior radiograph.
- Only the "Y" or axillary views can clearly demonstrate the dislocation type (**FIGURE 51.6**).
- There is a higher incidence of posterior glenoid rim and lesser tuberosity fractures.

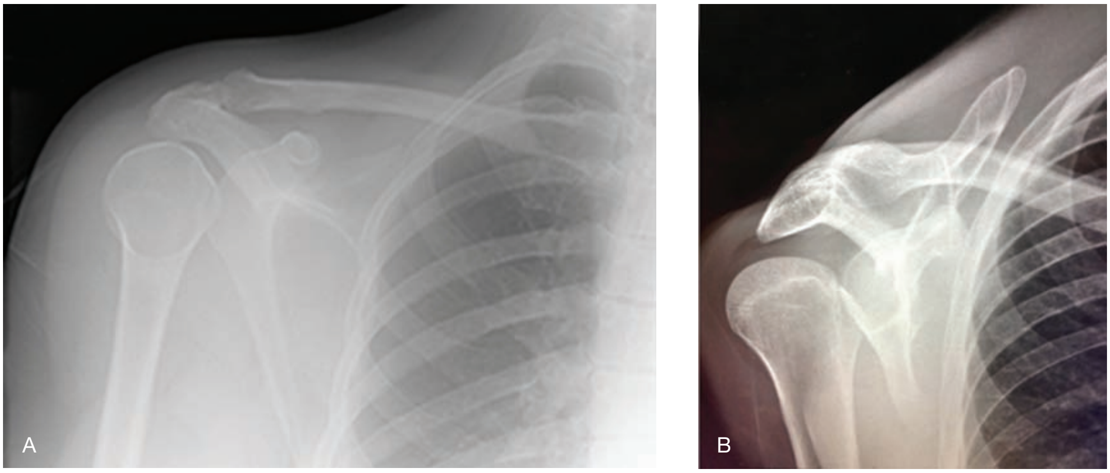

FIGURE 51.6 (A) X-ray of the anteroposterior view showing subtle signs of this posterior glenohumeral dislocation. (B) "Y" view clearly showing the posterior relationship of the humeral head relative to the glenoid fossa.

NOTE ***that the anteroposterior (AP) x-ray misses this diagnosis 50% of the time, although one can look for the following on a standard AP view:***

- *An internally rotated humeral head that appears round (light-bulb sign)*
- *Widening of the glenohumeral joint greater than 6 mm*
- *Loss of the normal half-moon overlap sign*
- *"Y" view is needed*

Inferior Dislocation

- The mechanism is extreme hyperabduction driving the humeral head through the inferior joint capsule (**FIGURE 51.7A**).
- These dislocations have a higher incidence of rotator cuff tears.

PATIENT PRESENTATION

Anterior Dislocation

- Injury causes severe pain.
- Injured extremity held by the contralateral arm with slight external rotation and abduction.
- The normal rounded contour of the shoulder is flattened with a shelflike appearance, secondary to a now-prominent acromion process (**FIGURE 51.8**).
- Anterior shoulder appears full.
- Patient is unable to use the ipsilateral hand to palpate the contralateral shoulder, otherwise known as the *scarf sign*.

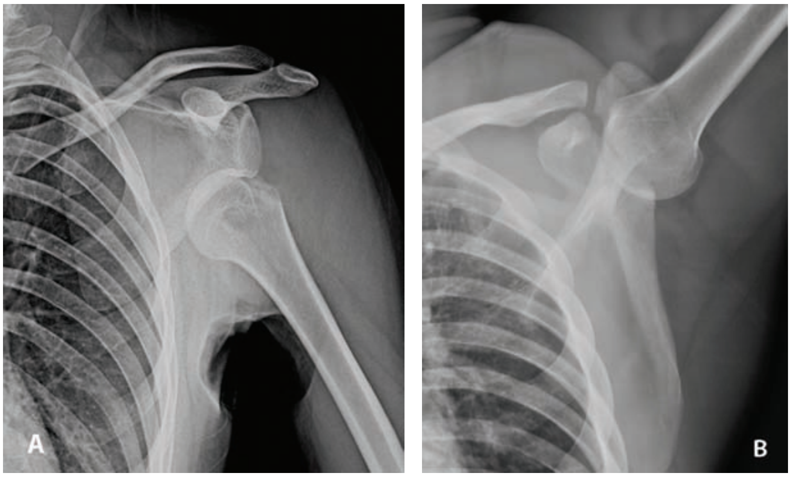

FIGURE 51.7 (A) An x-ray showing inferior subglenoid glenohumeral luxation. (B) An x-ray of a specific and rare type of an inferior shoulder dislocation, with the humeral head forced against the acromion and the humerus positioned in a cephalad manner; this is known as a *luxatio erecta* type of glenohumeral dislocation.

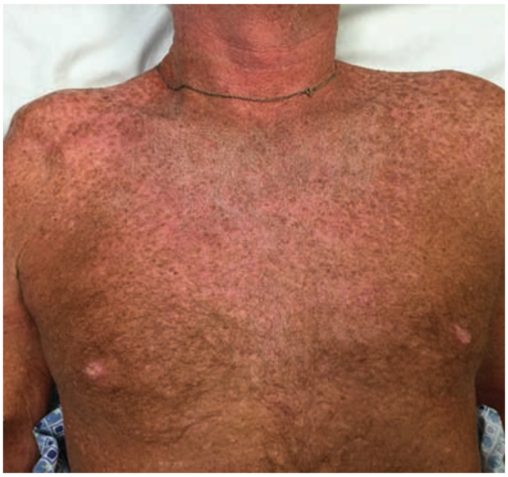

FIGURE 51.8 Photograph showing right anterior shoulder dislocation. Note obvious deformity and prominence of the acromion process, depression below this, and fullness in the anterior shoulder representing the displaced humeral head.

Posterior Dislocation

- Injury causes severe pain.
- Injured extremity held by the contralateral arm with slight internal rotation and adduction.
- The posterior shoulder appears full, whereas the anterior shoulder appears flat (**FIGURE 51.9**).

Inferior Dislocation

- Injury causes severe pain.
- Fully abducted humerus appears to be in a locked position.
- Elbow is flexed.
- Ipsilateral hand is near or behind the patient's head (**see FIGURES 51.7B** and **51.10**).
- Humeral head may be palpated along the thoracic wall.

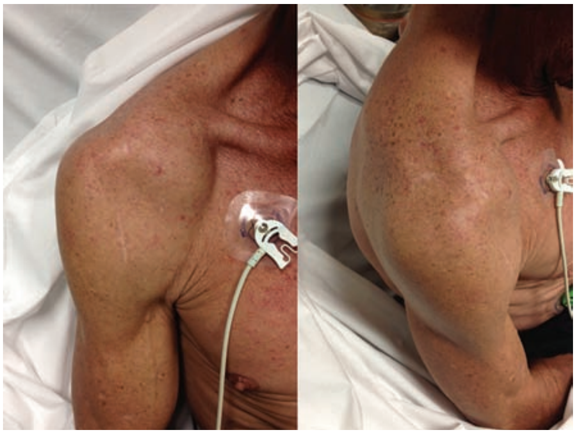

FIGURE 51.9 Note depression in the anterior shoulder and prominence in the posterior shoulder representing the displaced humeral head. This type is clinically less obvious compared to anterior dislocations.

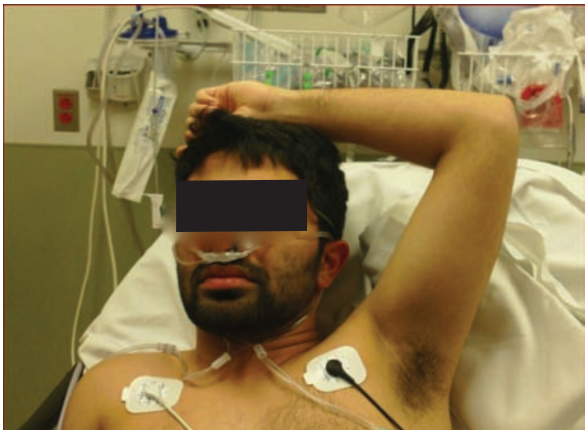
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FIGURE 51.10 Photograph showing the classic presentation of a specific and rare type of inferior shoulder dislocation, *luxatio erecta*. Note the ipsilateral arm is held up and behind the patient's head.

Imaging

X-RAYS

Prereduction films are often obtained to document the type of dislocation and to establish the existence of any associated pathology, such as a Hill–Sachs lesion, Bankart fracture, or a greater tuberosity fracture. In cases where patients have experienced repeated anterior dislocations, especially atraumatic, prereduction films may not be necessary prior to attempts at reduction.

- Anterior dislocations (**FIGURE 51.11**):
  - Anteroposterior (AP) view
    - Usually characterized by a subcoracoid or subglenoid position of the humeral head
  - Scapular ("Y") view
    - Humeral head lies anterior to the perpendicular view of the scapula/glenoid fossa
- Posterior dislocations (**FIGURE 51.12**):
  - AP view
    - Humeral head may resemble a light bulb/ice cream cone/top of a walking stick.
    - Often missed in up to 50% of the cases with a single AP view.
  - Scapular ("Y") view
    - Humeral head is posterior to the glenoid, and the radial head is inferior to the glenoid.
- Associated fractures are common and are reported in up to 30% of cases.
  - None of these fractures change emergent treatment:
    - Bankart
    - Hill–Sachs
    - Greater tuberosity

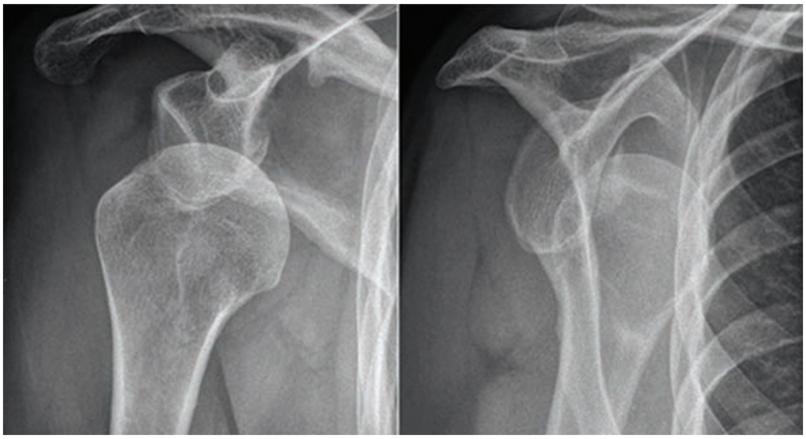


FIGURE 51.11 X-ray of the anteroposterior and scapular (Y) view showing typical anterior shoulder dislocation.

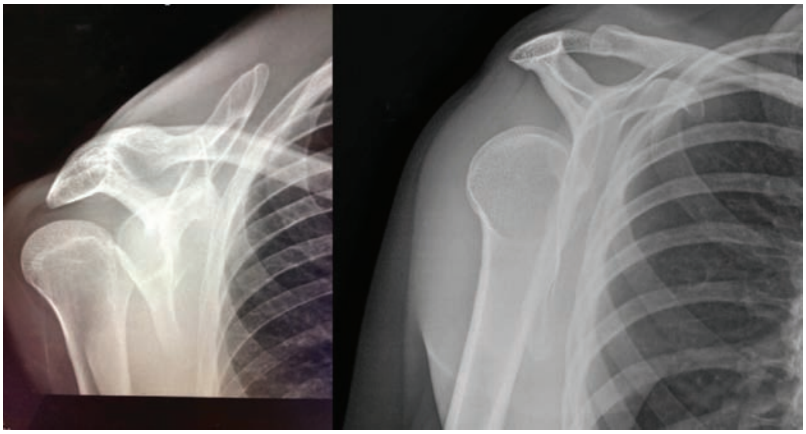


FIGURE 51.12 X-ray of the anteroposterior and scapular (Y) view showing typical posterior shoulder dislocation.

A **Bankart lesion** is an injury of the anterior–inferior glenoid rim/labrum due to anterior shoulder dislocation; it is a sign of recurrent luxations and, when this happens, a pocket at the front of the glenoid forms that allows the humeral head to dislocate into it (**FIGURE 51.13**).

A **Hill–Sachs deformity** is a compression fracture to the posterolateral aspect of the humeral head created by the glenoid rim during dislocation; typically, this occurs secondary to recurrent anterior shoulder dislocations as the humeral head comes to rest against the anteroinferior part of the glenoid (**FIGURE 51.14**).

A concomitant fracture of the **greater tuberosity** is seen in approximately 20% of patients presenting with anterior shoulder dislocation. This usually occurs in patients greater than 50 years old. Inherent muscle tension of the attached rotator cuff displaces the fragment dorsally and cranially from the dislocated humeral head fragment (**FIGURE 51.15**).

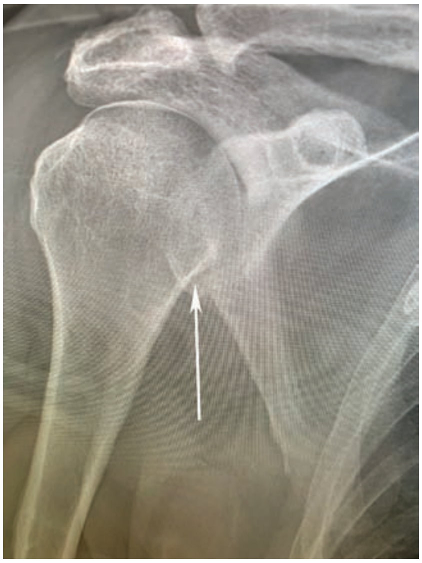


FIGURE 51.13 Bankart lesion.

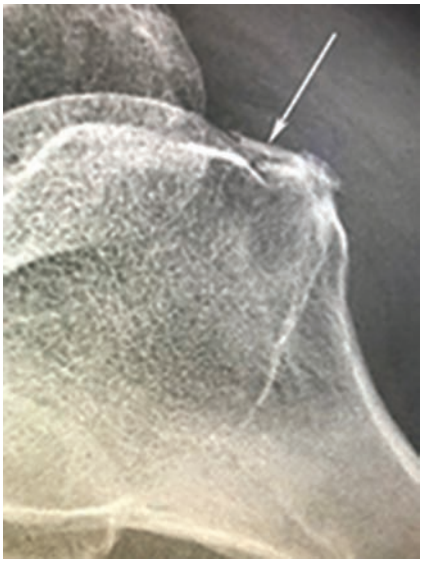


FIGURE 51.14 Hill–Sachs deformity.

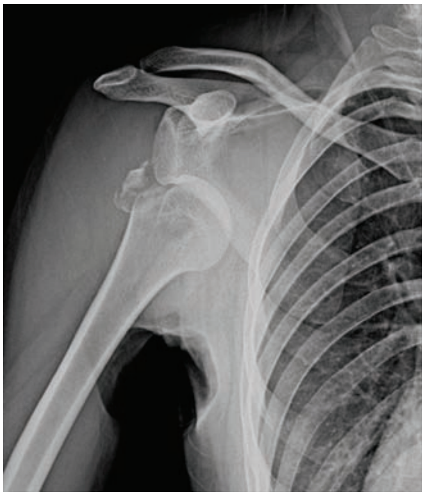


FIGURE 51.15 Inferior glenoid glenohumeral luxation with associated displaced greater tuberosity avulsion fracture. Nondisplaced or minimally displaced (<5 mm) fractures are usually treated nonoperatively and comprise the majority of such cases.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- In patients with a contraindication to sedation, such as intoxicated patients, POCUS-guided intraarticular anesthetic injection may be beneficial.
- Open dislocations are contraindicated.

SPECIAL CONSIDERATIONS

- In traumatic glenohumeral luxations, be cognizant that the same kinetic energy that causes a glenohumeral dislocation may also be transmitted to the chest.
- In these scenarios, when reviewing the shoulder x-ray, the astute clinician should study the thorax first for accompanying injuries such as pneumothorax, pulmonary contusions, and rib fractures (**FIGURE 51.16**).

PROCEDURE PREPARATION/REDUCTION TECHNIQUE

- Prepare for conscious sedation (cardiac monitor, pulse oximeter, end-tidal carbon dioxide [ETCO$_2$], etc.)
- Assistant
- Two sheets

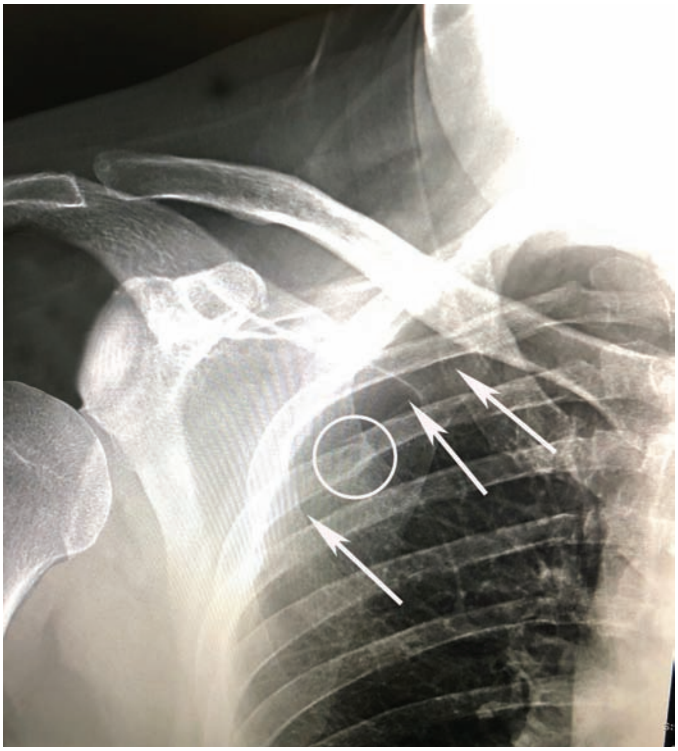


FIGURE 51.16 In this shoulder x-ray, it may be easy to be fixated on the obvious pathology, a glenohumeral subglenoid dislocation, and overlook the associated and less obvious rib fracture (*circle*) and pneumothorax (*arrows*).

PROCEDURE

Anterior Modified Traction—Countertraction

- Patient is supine with the arm abducted and elbow flexed at 90 degrees.
- Tie and wrap a sheet around the waist of the clinician with the other end placed in the antecubital fossa of the patient at the flexed elbow.
- An assistant has another sheet wrapped across the chest of the patient at the level of the axillae, applying countertraction (**FIGURE 51.17** and **VIDEO 51.1**).
- The clinician leans back (traction) while rotating the arm externally and possibly internally. Traction should be applied in a steady fashion, avoiding jerking movements.
- Pressure applied to the head of the humerus in the direction of the glenoid fossa may facilitate this technique.

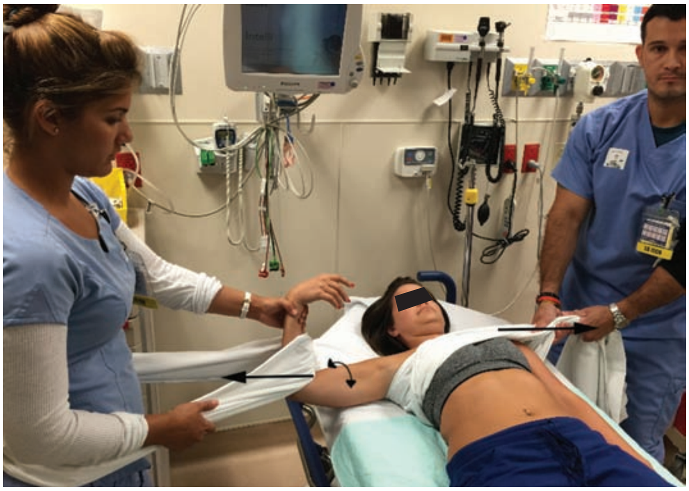
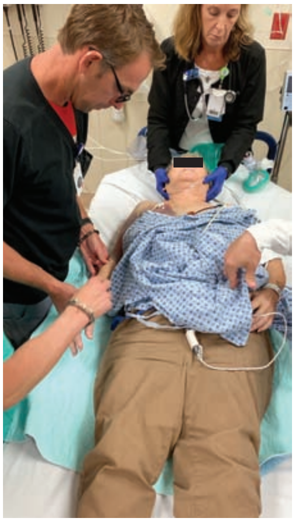


FIGURE 51.17 Modified traction–countertraction method.



VIDEO 51.1 Modified traction–countertraction method.

External Rotation (Kocher Method)

- Patient is supine with the arm adducted to the side.
- Gradually, the elbow is flexed to 90 degrees, while slow forearm external rotation is applied until the arm lies in the coronal plane (**FIGURE 51.18**, and **VIDEO 51.2**).
- This should take place slowly, with the position held if the patient experiences significant pain; full external rotation may take as much as 5 to 10 minutes.
  - The externally rotated upper arm is lifted in the sagittal plane as forward as possible, and the shoulder is internally rotated to bring the patient's hand toward the opposite shoulder.
- A "clunk" sound may not be appreciated by the clinician or the patient. Once reduction occurs, the arm is internally rotated to bring the forearm into abduction. Occasionally, reduction may not occur until this final maneuver.
- This technique may be attempted without sedation in the appropriate patient.
  - Janitzky et al. (2015) retrospectively reviewed the external rotation method without sedation and analgesia.
  - They found that in 79% of the 139 patients studied without any sedation or analgesia, this technique was successful.
- Also of benefit, this technique requires only one clinician.
- Pressure applied to the head of the humerus may facilitate this technique.

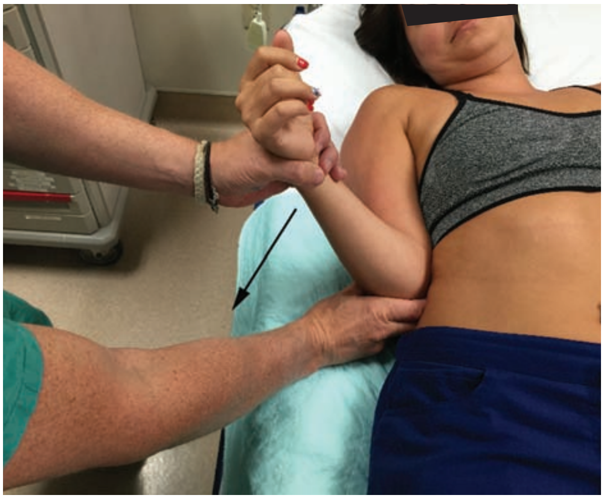
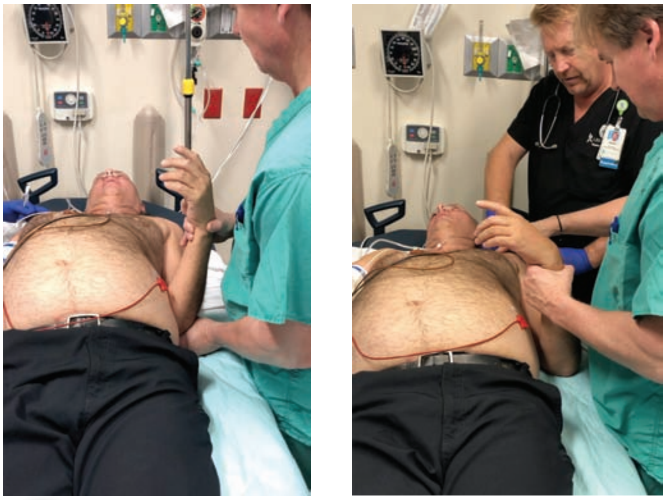


FIGURE 51.18 External rotation. Note the importance of keeping the humerus fully adducted and the elbow adhered to the patient's torso. Slow constant movement increases success.



VIDEO 51.2 External rotation technique.

Scapula Manipulation

Reduction is accomplished by repositioning the glenoid fossa rather than the humeral head. McNamara (1993) has shown the success to be 86%, and in two-thirds of the patients studied, no pretreatment medications were required.

- The patient is placed in the prone position.
- Traction is applied on the ipsilateral arm, which is hanging off the bed at 90 degrees of forward flexion, with traction via an assistant or weights.
- May also be done with the patient sitting upright with the clinician behind the patient and an assistant in front applying traction on the outstretched arm while they are applying simultaneous countertraction on the ipsilateral clavicle (**FIGURE 51.19**).
- The clinician pushes the inferior tip of the scapula with two thumbs medially and superiorly while stabilizing the superior scapula with the top hand,

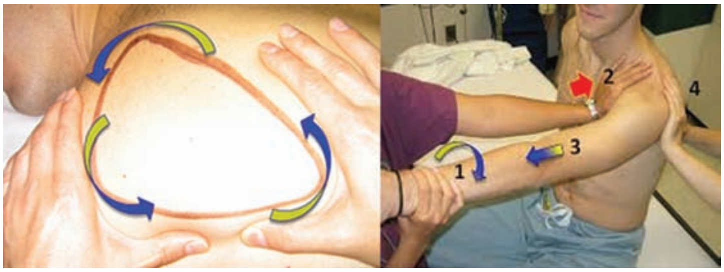


FIGURE 51.19 Scapular manipulation method. Prone and sitting techniques shown.

which causes the glenoid to move anteriorly and caudally to meet the humeral head. Note that the tip of the scapula may be quite laterally positioned in patients with anterior dislocation.

- This technique may be attempted without sedation in the appropriate patient.
- This can be difficult in heavier patients as landmarks are diminished.

Milch Technique

In the fully abducted and overhead position, the shoulder muscles are in an effusively relaxed locus.

- Patient is supine while the clinician stands behind the stretcher and fully abducts and externally rotates the arm to the complete overhead position as if the patient was reaching for an apple from a tree by means of grasping the near fully extended elbow and wrist (**FIGURE 51.20**).
- Traction is applied in the longitudinal direction of the humerus.
- May apply upward pressure to the humeral head with the contralateral hand.
- The FARES (fast, reliable, and safe) method is also known as the *modified Milch* and involves slow abduction of the affected limb with small oscillating movements until reaching 90 degrees, at which point the limb is externally rotated and abduction continues until reduction is achieved.

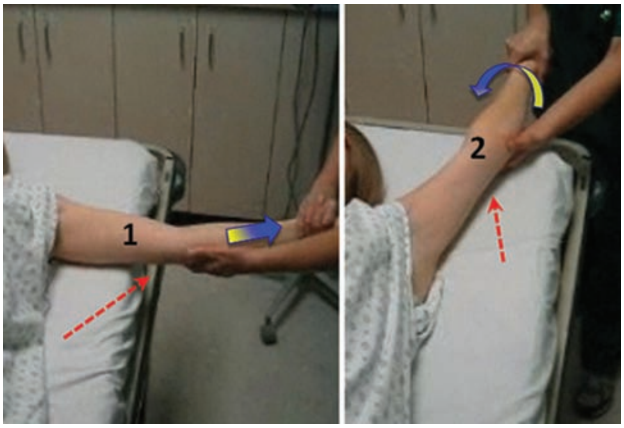


FIGURE 51.20 Milch technique for reduction in anterior shoulder dislocation. Note clinician stands behind stretcher and the humerus is fully abducted and the elbow extended.

Cunningham Technique

- The patient and clinician are seated and facing each other.
- The patient places the hand of the affected arm on the clinician's upper arm.
- The clinician places their hand on the patient's elbow and provides gentle downward traction to the affected arm (**FIGURE 51.21**). Simultaneously, the clinician massages the trapezius, deltoid, and biceps muscles.

Spaso Technique

- The patient is supine on the bed with affected arm held vertically, straight up toward the ceiling.
- The clinician, standing near the patient's head on the affected side, provides vertical traction (toward the ceiling) and simultaneous external rotation of the affected arm (**FIGURE 51.22**).

Elbow Technique

- The patient is supine with the clinician standing on the affected side.
- The clinician provides traction with the outer hand to straighten the patient's elbow.
- The clinician places the elbow of the inner arm against the patient's antecubital fossa.
- By providing superiorly directed force, the clinician creates a lever with their own elbow as a fulcrum, allowing the humeral head to be reduced (**FIGURE 51.23**).

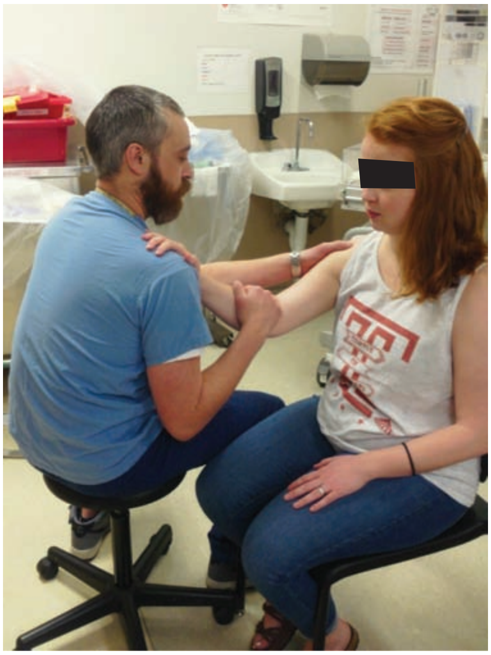


FIGURE 51.21 Cunningham technique for reduction of anterior shoulder dislocation.

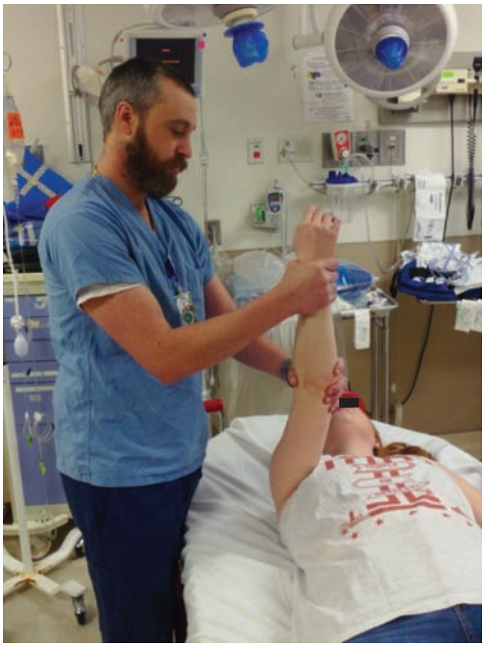


FIGURE 51.22 Spaso technique for reduction of anterior shoulder dislocation.

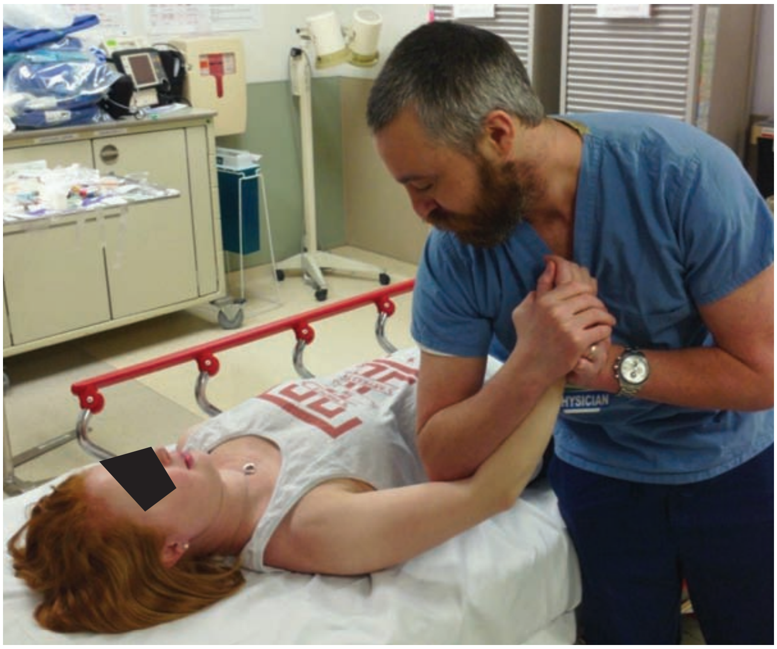


FIGURE 51.23 Elbow technique for reduction of anterior shoulder dislocation.

Snowbird Technique

- The patient is seated in a chair with the affected arm over the back of the chair (not shown in photo) and the clinician standing in front, facing the patient.
- A loop of cloth bandage or gauze role is draped around the patient's affected elbow, which is flexed 90 degrees.
- The clinician places their foot into the loop and pushes down to create downward traction on the affected arm.
- An assistant, on the opposite side of the patient, provides countertraction with a sheet wrapped around the patient's body to keep the patient upright and provide countertraction (**FIGURE 51.24**).

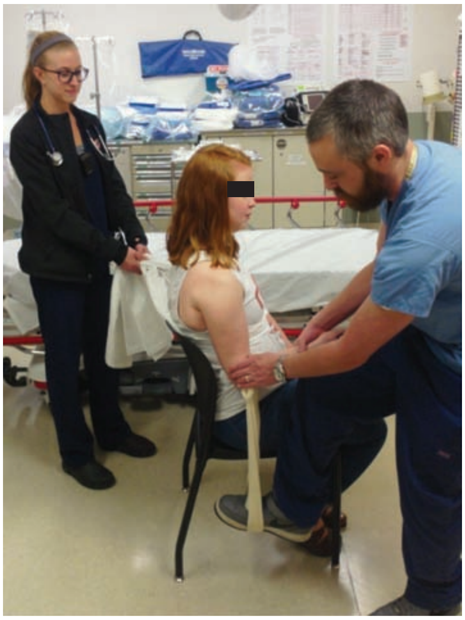


FIGURE 51.24 Snowbird technique for reduction of anterior shoulder dislocation.

Stimson Technique

- The patient lies prone on the bed with the affected arm hanging down toward the ground.
- Weights (often saline bags) are tied to the patient's affected arm or held by the patient in the affected hand. This often requires the bed to be elevated so the weights are not resting on the ground.
- Downward traction provided by the weights allows for ***passive reduction*** of the affected shoulder.
- Care should be taken to ensure the patient does not fall off the bed, especially in those patients who have been given an anxiolytic or procedural sedation (**FIGURE 51.25**). Seat-belt straps or bed sheets can be used for this purpose.

Posterior Traction–Countertraction Technique

- Patient is supine with the arm adducted.
- As in the modified traction–countertraction technique described in anterior dislocations, tie and wrap a sheet around the waist of the clinician with the other end placed over the antecubital fossa of the patient at the flexed elbow.

- An assistant has another sheet wrapped across the chest of the patient at the level of the axillae and applies countertraction.
- The clinician leans back and applies traction in the long axis of the humerus.
- An assistant applies anterior pressure to the posteriorly displaced humeral head (**FIGURE 51.26**).
- Lateral traction to the proximal humerus facilitates this technique.

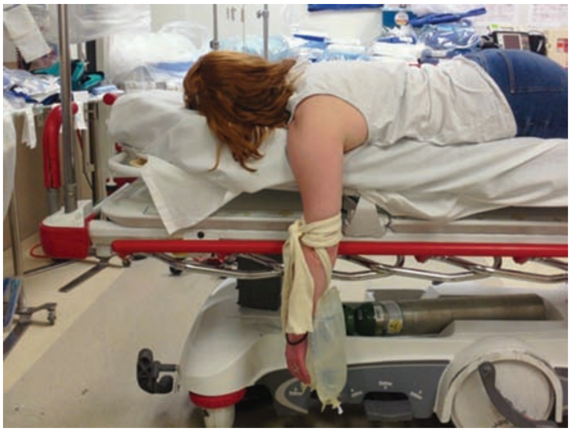


FIGURE 51.25 Stimson technique for reduction of anterior shoulder dislocation.

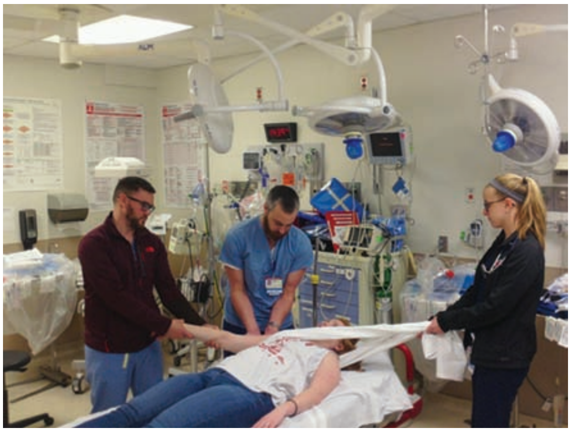


FIGURE 51.26 Traction–countertraction maneuver for reduction of posterior shoulder dislocation.

Lever Arm Technique

- The patient is supine on the bed with the clinician standing on the affected side (**FIGURE 51.27**).
- The clinician provides inferior traction on the affected arm toward the patient's feet as well as internal rotation.
- The clinician then uses their other arm to press underneath the patient's affected arm, bracing the patient. This creates a lever by which the humeral head can be moved laterally and ventrally for reduction.

Inferior Modified Milch With Countertraction Technique

- Apply traction in an upward direction in line with the humerus similar to the Milch technique.
- An assistant has another sheet wrapped across the chest of the patient at the level of the axillae, applying countertraction.
- May employ cephalad pressure over the humeral head (**FIGURE 51.28**).

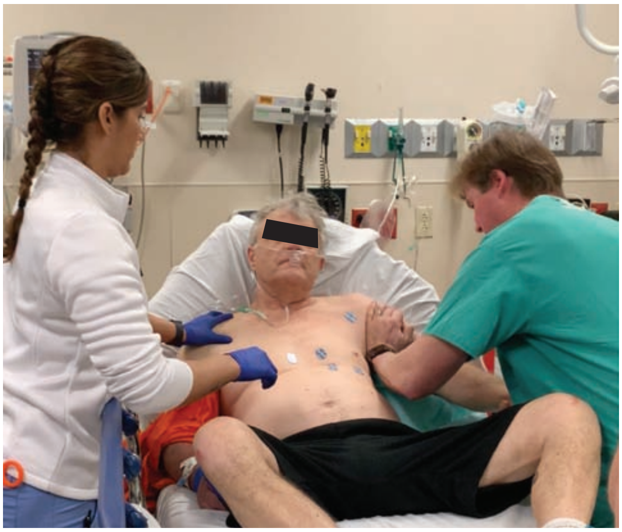


FIGURE 51.27 Lever arm technique.

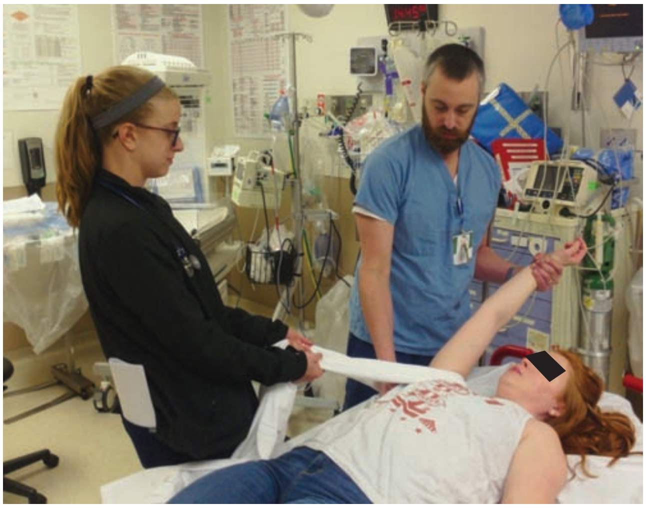


FIGURE 51.28 Modified Milch with countertraction technique for reduction of posterior shoulder dislocation.

Two-Step Method

- The patient is supine with the affected arm above the head (inferior dislocation) and the clinician stands next to the patient on the affected side.
- The clinician first provides anterior force from behind the patient's affected arm while pulling posteriorly on the patient's elbow.
- This allows the inferior dislocation to be converted to an anterior dislocation, which can then be reduced by any of the methods described, though the creators of the two-step method recommend adduction and external rotation of the humerus.

Comparisons

- A 2017 systematic review examined 23 different techniques for closed reduction of an anterior shoulder dislocation with 17 different modifications.
- Techniques were compared for reduction success, reduction time, mean hospital stay, and pain, as well as complications.
- Scapular manipulation was found to be the most successful, fastest, and least painful reduction technique for anterior shoulder dislocations with a 97% success rate and a time of 1.75 minutes.
- The FARES or modified Milch technique was similar with a 92% success rate and a reduction time of 2.24 minutes.
- **The traction–countertraction method was also shown to be highly successful at 95% but was noted to be slower and associated with more pain.**

ULTRASOUND GUIDANCE

Typically, plain-film radiography is utilized to diagnose shoulder dislocation and evaluate for fractures. However, recent literature has demonstrated the advantage of point-of-care ultrasound (POCUS) in detecting both anterior and posterior shoulder dislocations (**FIGURES 51.29**, **51.30**, **51.31**, and **VIDEO 51.3**). In a prospective observational study of 73 patients, Gottlieb and Russell (2017) have shown that POCUS was 100% sensitive and specific for the diagnosis of dislocation. Furthermore, POCUS can be used to help guide intraarticular anesthetic injections. Emond et al. (2004) have shown that when all three factors in the list that follows were met (risk stratification for a low fracture risk), the negative predictive value (NPV) for the presence of a fracture was 97%:

- Young age (<40 years old)
- History of multiple dislocations
- Atraumatic mechanism

If the preceding criteria are met and the clinician feels that this is an uncomplicated anterior shoulder dislocation, prereduction radiographs are unnecessary. Further investigation is necessary to assess the ability of POCUS in detecting associated fractures.

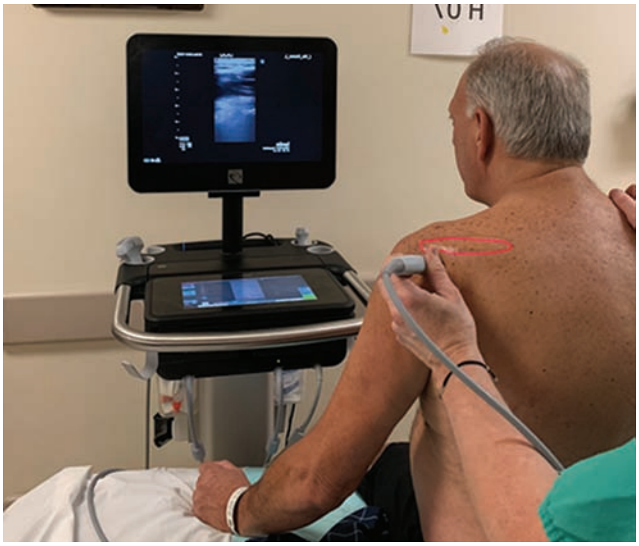


FIGURE 51.29 Point-of-care ultrasound of posterior glenohumeral joint. Note one should use the high-frequency linear probe in thinner patients and the curvilinear lower frequency curve probe in larger patients. Use the horizontal scapular spine as a landmark and slide the posterior transverse probe laterally just under the scapular spine until the glenoid and humeral head are visualized. Ensure the ultrasound monitor is within one's line of vision.

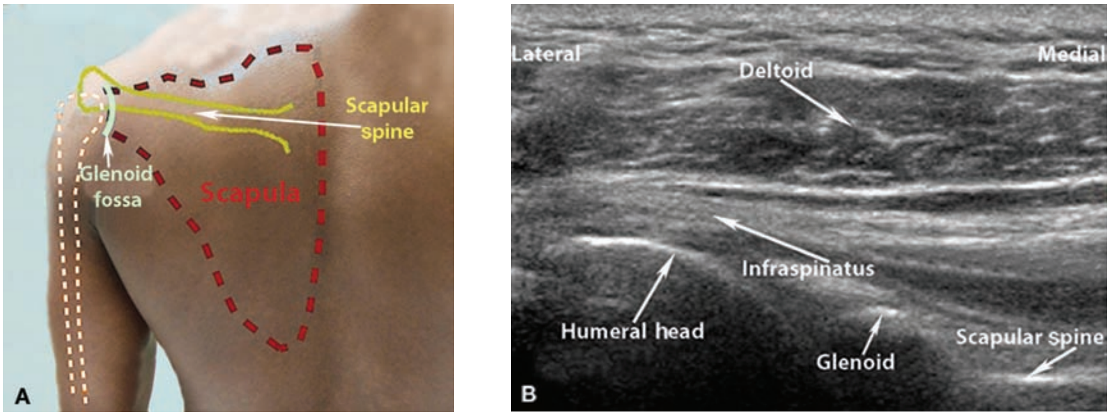

Scapular spine
Glenoid fossa
Scapula
A
Lateral
Medial
Deltoid
Infraspinatus
Humeral head
Glenoid
Scapular spine
B

FIGURE 51.30 (A) Normal posterior surface shoulder anatomy. (B) Posterior ultrasound view of a normal glenohumeral joint.

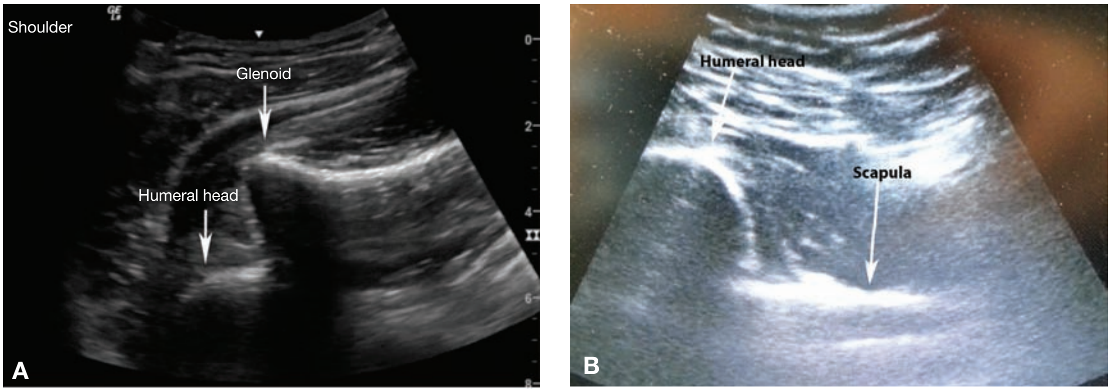
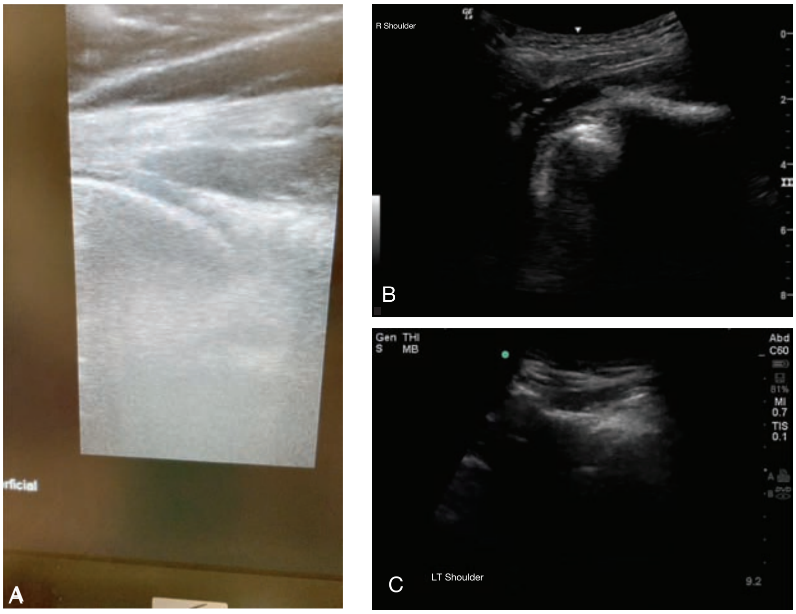

Shoulder
Glenoid
Humeral head
A
Humeral head
Scapula
B

FIGURE 51.31 (A) Anterior–inferior luxation. Note the inferior position of the humeral head in relation to the glenoid and its smaller appearance (further from the probe). (B) Posterior glenohumeral luxation. Note the superior position of the humeral head and its larger size shown from the posterior view (closer to the probe).


rficial
A
R Shoulder
B
Gen THI
S MB
Abd
C60
81%
MI
0.7
TIS
0.1
LT Shoulder
9.2
C

VIDEO 51.3. (A) Normal glenohumeral joint relationship through internal and external rotation. (B) Anterior glenohumeral dislocation. (C) Posterior glenohumeral dislocation.

Relative to x-rays, POCUS potentially allows for:

- Greater diagnostic efficiency
- Improved accuracy for detection
- Dynamic evaluation of the glenohumeral joint
- Decreased length of stay (LOS)
- Decreased error rate
- Immediate evaluation of reduction attempts

Reduction Techniques

Regardless of the technique used, the astute clinician should be familiar with multiple reduction techniques, as no technique carries a 100% success rate. Procedural sedation is often required, though POCUS-guided intraarticular lidocaine or parenteral analgesia may suffice in selected circumstances (**FIGURE 51.32**). Basically, all techniques involve a form of traction, leverage, or scapular manipulation. Essentially the clinician is either moving the humeral head, the glenoid fossa, or both.

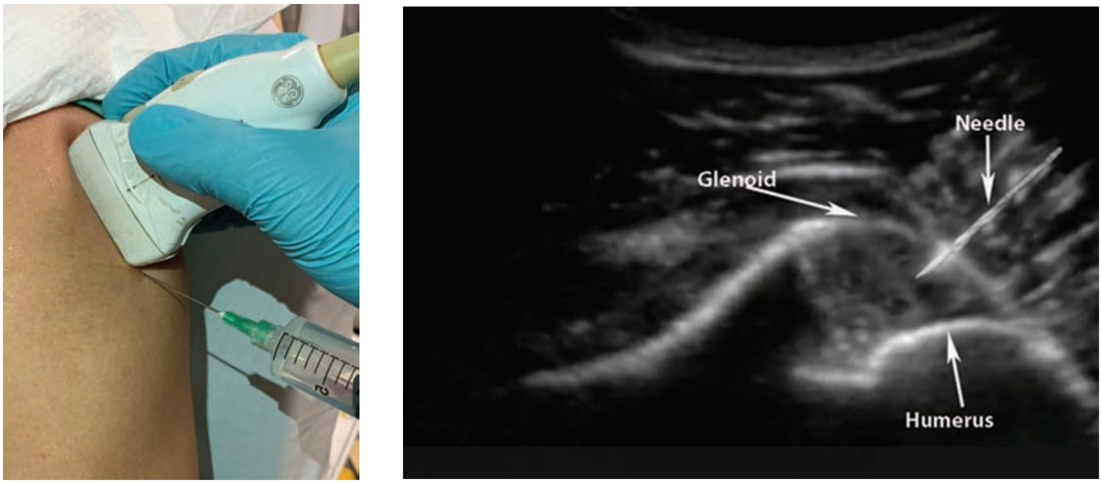


FIGURE 51.32 POCUS-guided intraarticular local anesthetic injection.

POCUS, point-of-care ultrasound.

POSTPROCEDURE CONSIDERATIONS

- Typically, after reduction, all patients should be placed in a sling and swathe and should follow up with orthopedics.
  - Arrange orthopedic follow-up in 5 to 7 days. The patient's shoulder should remain in the immobilizer until their orthopedic clinic appointment.
  - Primary surgical repair of initial acute shoulder dislocations is in general not recommended.
    - However, in the subset of patients who are younger and engaged in demanding sporting activities, surgery is supported by a Cochrane review of five randomized controlled studies showing that subsequent shoulder instability was significantly less frequent in the surgical group (relative risk, 0.20), with half of the conservatively treated patients opting for subsequent surgery; functional assessment measures of the shoulder were also more favorable in those treated surgically. Because this demographic group is at far greater risk of recurrent dislocation, these results cannot be generalized to other groups.
  - Rotator cuff tears may accompany anterior and inferior glenohumeral dislocations; the frequency of this complication increases with age:
    - Greater than 40 years old—30%
    - Greater than 60 years old—80%
    - Presents later as persistent pain or weakness on external rotation and abduction

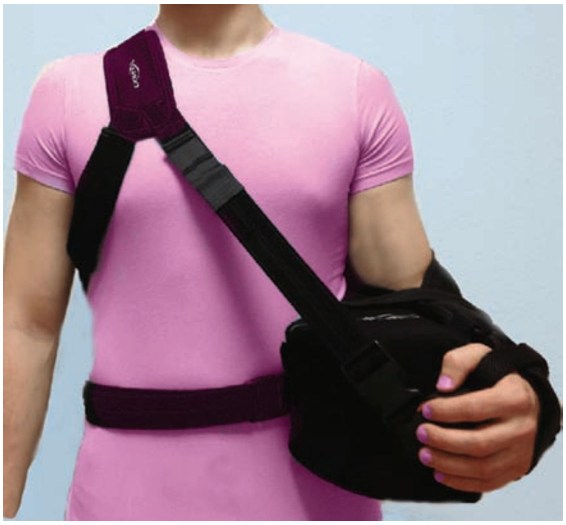


FIGURE 51.33 External rotation immobilization.

- Note that current evidence suggests immobilization for 3 weeks of a first-time traumatic shoulder dislocation in external rotation as this may reduce the risk of recurrent dislocation as compared to standard internal rotation immobilization, although this is still under debate (**FIGURE 51.33**). However, most still provide a traditional shoulder immobilizer at the time of ED discharge.
- Proper analgesics should be given.
- Although most clinicians perform x-rays after reduction, if the patient displays stability of the joint with a normal neurological exam, and is able to take the ipsilateral hand and touch the contralateral shoulder, the clinician may consider foregoing postreduction radiography.
  - The Quebec Decision Rule for Radiography in Shoulder Dislocation study has shown that by using certain clinical criteria, prereduction imaging can be reduced by 28% and postreduction studies by 82%. The sensitivity and NPV for ruling out a clinically significant fracture was shown to be 100% and 99.2%, respectively. The prospectively derived four risk factors warranting imaging are:
    - Age ≥40 years old
    - Mechanism (motor vehicle collision, assault, sporting injury, fall from a distance greater than patient's height)
    - Presence of humeral ecchymosis
    - First episode of dislocation

EDUCATIONAL POINTS

- In the traumatically induced shoulder dislocation, look for associated injuries both clinically and radiographically.
- The glenohumeral articulation is the most commonly dislocated joint in the body.
- Axillary neuropraxia is the most common nerve injury in shoulder dislocations; always test for such before and after reduction.
- Older patients have a much higher rate of accompanying rotator cuff injuries though a lower rate of recurrent dislocations compared to their younger counterparts.
- AP radiographs miss up to 50% of posterior glenohumeral luxations; be sure to get a scapular "Y" view when clinical suspicion dictates.
- POCUS has been shown to be 100% sensitive and specific for the diagnosis of shoulder dislocation; embrace this bedside modality.
- Postreduction x-rays are done in order to diagnose associated fractures; however, the literature states that in certain patients it may be unnecessary:
  - Young age (< 40 years old)
  - History of multiple dislocations
  - Atraumatic mechanism
- A 2017 study has shown that scapular manipulation is the most successful, fastest, and least painful reduction technique for anterior shoulder dislocations.
- It is crucial to overcome the muscular resistance of the patient during these maneuvers; if a reduction maneuver is continued persistently against resistance, complications, such as excessive pain or fracture (e.g., humeral neck fractures during reduction of anterior shoulder dislocation, particularly in osteoporotic bones) and axillary/brachial plexus nerve damage, may occur.
- External rotation and scapular manipulation may be attempted without sedation or analgesia in the appropriate patient.

COMPLICATIONS

- Fracture
  - Bankart
  - Hill–Sachs
  - Greater tuberosity
- Axillary nerve injury
- Rotator cuff injury

PEARLS

- Younger patients usually redislocate; older patients usually do not.
- The same anatomic features that contribute to the extreme mobility of the glenohumeral joint contribute to it being representative of 50% of all major joint dislocations.
- Older patients may have associated rotator cuff injury, while younger patients usually do not.
- Posterior dislocations are often missed radiographically. A "Y" view will show the anterior/posterior relation of the humeral head and the glenoid fossa.
- Gradual, gentle traction and rotation, along with maximal muscular relaxation, are the cornerstones to successful reduction techniques.
- Avoid jerking forces because this increases complications and decreases success rates.
  - Sometimes more than one technique is attempted for the successful reduction of the shoulder.
  - Become familiar with many techniques for reducing anterior dislocations of the shoulder, because no single method has a 100% success rate.
- If a patient can take the ipsilateral hand and touch the contralateral shoulder (scarf sign), there is no dislocation (**FIGURE 51.34**).
- Anteroinferior glenoid fractures/labral tears (Bankart deformity) are present in many anterior shoulder dislocations, and contribute to instability and recurrent dislocation.
- The presence of humeral head fractures (Hill–Sachs deformity) also correlates with recurrent dislocation.
- Ultrasound is being used more often to complement clinical confirmation of dislocation and adequate reduction.
- Luxatio erecta (inferior) dislocations are always associated with an inferior joint capsule tear.

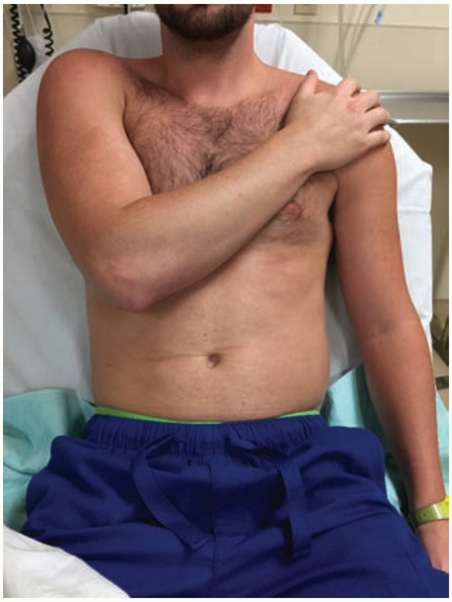


FIGURE 51.34 Scarf sign.

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CHAPTER

52

Elbow Dislocation

Matthew Tripod, Keith Lafferty, and Edward Siegel

BACKGROUND

Anatomically, the elbow is considered a large hinge joint that is formed principally between the humerus and the ulna to allow for flexion and extension of the arm. However, this complex joint is composed of two additional articulations, the radiohumeral joint and the radioulnar joint. The articular surfaces are highly congruent and the joint is augmented by ligamentous complexes and muscles, which strengthen its configuration. This combination of static and dynamic stabilizers allows the elbow to withstand high-energy forces. ***Despite the inherent stability in the joint, in adults, the elbow is the second most commonly dislocated large joint after the shoulder and is the most commonly dislocated joint in children***. The reported incidence ranges from 2.7 to 6.1 per 100,000 people; 57% of dislocations result from falls, whereas 44% are secondary to a sporting injury.

The lateral collateral ligament (LCL) and medial collateral ligament (MCL) provide the primary ligamentous support for the joint as they comprise the majority of the joint capsule (**FIGURE 52.1**). They can be disrupted partially or fully when there is a dislocation and the degree of this disruption is related to future stability of the joint. In a randomized trial comparing surgical and nonsurgical treatment of ligament injuries after simple elbow dislocation in 30 patients examined under anesthesia, Josefsson, Johnell, and Gentz (1984) found all had complete disruption of the MCL and about half involved some degree of injury to the LCL.

To maintain its integrity, the elbow relies more on its bony configuration than on its ligamentous support; specifically, the articulation of the trochlea of the distal humerus and the olecranon fossa of the proximal ulna medially comprise the majority of the humeroulnar joint.

The considerable force necessary to dislocate the elbow makes associated fractures of the radial head and coronoid process of the ulna common, reported in up to one-third of cases.

- *Complex dislocations*—Dislocations that have associated fractures and may require surgery
  - "Terrible triad"—Term referring to fractures of the radial head and ulnar coronoid process with an associated dislocation
- *Simple dislocations*—Dislocations without fractures; these comprise the majority of dislocations (two-thirds)

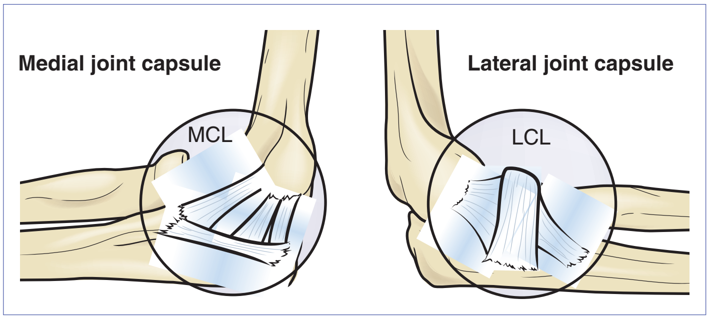


FIGURE 52.1 Elbow joint.
LCL, lateral collateral ligament; MCL, medial collateral ligament.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

The position of the olecranon in relation to the humerus further classifies elbow dislocations. Posterior and posterolateral dislocations are the most common types, comprising 90% of all dislocations.

Falls on an outstretched hand ("FOOSH") are common mechanisms resulting in dislocation, and thus sports activities account for up to 50% of elbow dislocations (**FIGURE 52.2**). As a result, this type of injury is more commonly seen in those younger than 30 years old and is slightly more predominant in males. The sports most often associated with this injury are wrestling, football, and gymnastics.

Note that ***children have a more immature/weaker distal humeral metaphysis in comparison to the ligamentous support*** and, although elbow dislocations are the most common type of joint dislocation in children, the same FOOSH mechanism may result in a supracondylar fracture in the pediatric age group.

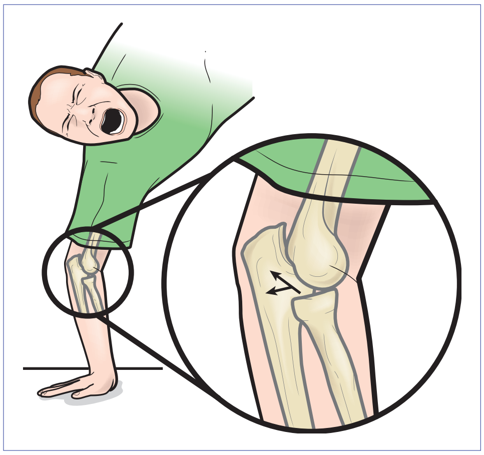


FIGURE 52.2 Falling on the outstretched hand.

Anatomy

ARTICULATIONS

The elbow is composed of three articulations **(FIGURE 52.3)**:

- Ulnohumeral (ulnotrochlear joint)
  - Flexion up to 150 degrees and extension to 0 degree
  - A primary joint stabilizer
- Radiohumeral (radiocapitellar joint)
  - Supination and pronation
  - A secondary joint stabilizer
- Radioulnar joint
  - Supination and pronation

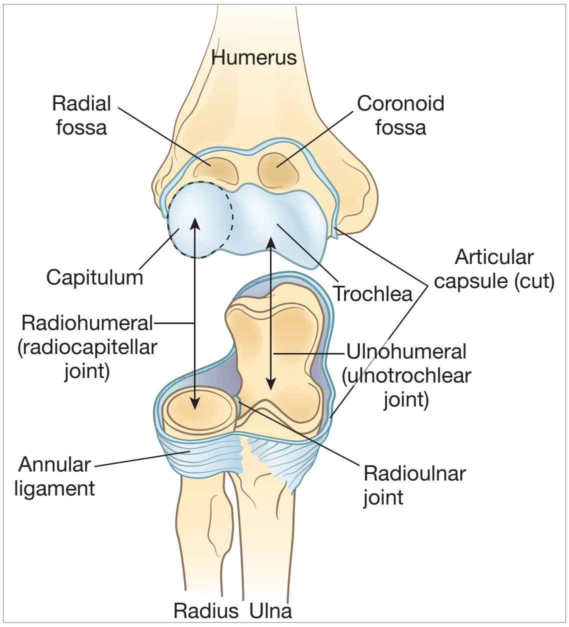


FIGURE 52.3 Elbow articulations.

LIGAMENTS

Ligaments are shown in **FIGURE 52.1**.

- MCL
  - A primary joint stabilizer
  - Provides resistance to valgus stress
  - Consists of three main bands:
    - Anterior oblique
      - Responsible for the majority of the stabilization conferred by the ligament
    - Posterior oblique
    - Transverse
- LCL
  - A primary joint stabilizer
  - Provides resistance to varus stress
  - Consists of three parts:
    - Radial collateral ligament
    - Ulnar collateral ligament
    - Acessory collateral ligament
- Annular ligament
  - Prevents radial head dislocation throughout the range of pronation and supination
  - Often included as part of the LCL complex
  Subluxation of this structure results in a nursemaid's elbow in the child less than 5 years old (see Chapter 57).

ARTERIES

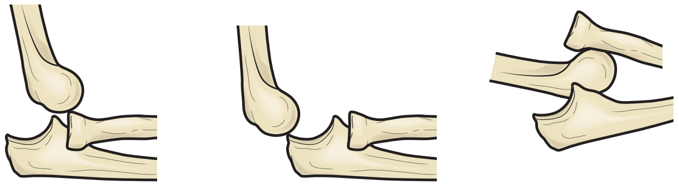
- The brachial artery is centrally located anterior to the elbow and eventually divides into the radial and ulnar artery in the proximal forearm.
    - The radial and ulnar artery, along with the brachial and the deep brachial artery, comprise an intricate anastomosis of vessels around the elbow, including the radial and ulnar collateral arteries and the radial and ulnar recurrent arteries.

NERVES

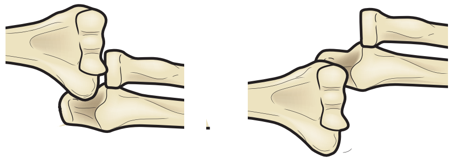
- The median nerve runs in the medial bicipital groove of the arm along with the brachial artery, passing over the brachial artery and under the bicipital aponeurosis near the elbow, staying medial to the brachial artery.
    - ***Median nerve involvement after closed reduction requires open exploration.***
- The radial nerve runs in the posterior compartment of the arm in the radial groove of the humerus and wraps laterally to its position near the elbow, where it is anterior to the lateral epicondyle.
- The ulnar nerve lies in the medial arm and near the elbow; it passes just posterior to the medial epicondyle of the humerus.
    - ***Ulnar nerve neuropraxia is the most commonly reported; however, these injuries generally resolve following closed reduction.***

Types of Dislocations

Various types of elbow dislocations are shown in **FIGURE 52.4**.



Posterior elbow dislocation **Anterior elbow dislocation** **Divergent elbow dislocation**



Medial elbow dislocation **Lateral elbow dislocation**

FIGURE 52.4 Types of elbow dislocations.

POSTERIOR

- FOOSH
    - Accompanied valgus force may induce a posterior lateral dislocation.
    - Olecranon forced posterior to the humerus.
    - ***FOOSH injuries account for 90% of elbow dislocations.***

ANTERIOR

- Caused by a strong blow to the posterior aspect of a flexed elbow.
- This force propels the olecranon anterior, relative to the humerus.
- This type of dislocation is associated most often with fractures.
- Anterior dislocations and any open fracture are commonly associated with disruption of the brachial artery and/or injury to the median nerve.

DIVERGENT

- This type of dislocation combines axial compressive with rotational forces on an outstretched, pronated arm.
- Very rare injury that is associated with significant high-energy trauma to the elbow.

MEDIAL/LATERAL

- Associated with posterior dislocations
- There are two main fascial compartments:
    - Anterior
        - This type of dislocation is a cause for concern, considering the proximity of the brachial artery as well as the ulnar and medial nerves.
    - Posterior

PATIENT PRESENTATION

In general, elbow dislocations are classified as follows:

- Simple—50% to 80%
  - No fracture
  - Closed
- Complex
  - Fracture
  - Terrible triad requires surgery; may be grossly unstable and difficult to maintain reduction
    - Dislocation
    - Radial head fracture
    - Coronoid fracture
  - May require CT scan if x-ray is inconclusive or to better characterize a comminuted fracture

Posterior

- FOOSH is most common cause (**FIGURE 52.5**)
- Deformity with a prominent olecranon creating a divot over the distal tricep (**FIGURE 52.6**).
  - The olecranon is displaced from the plane of the epicondyles disparate to a supracondylar fracture, in which the epicondyles are palpable in the same plane as the olecranon.
- Held in slight flexion
- Forearm shortened
- Essentially no range of motion (ROM)
- Pain
- Swelling

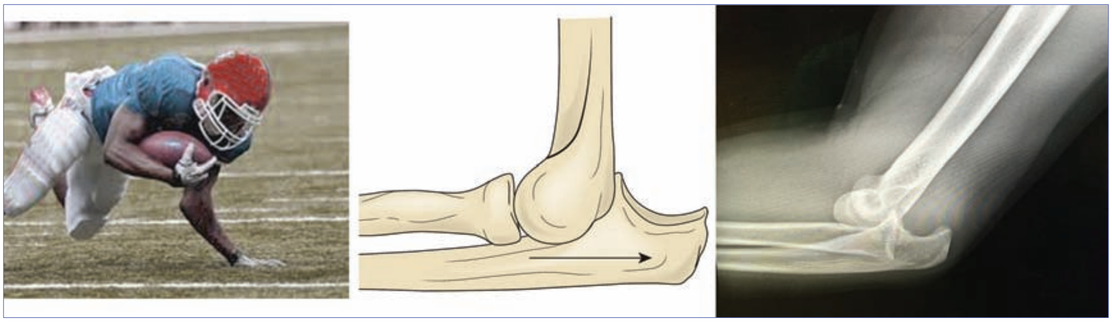


FIGURE 52.5 Posterior elbow dislocation next to gross sketch and x-ray.

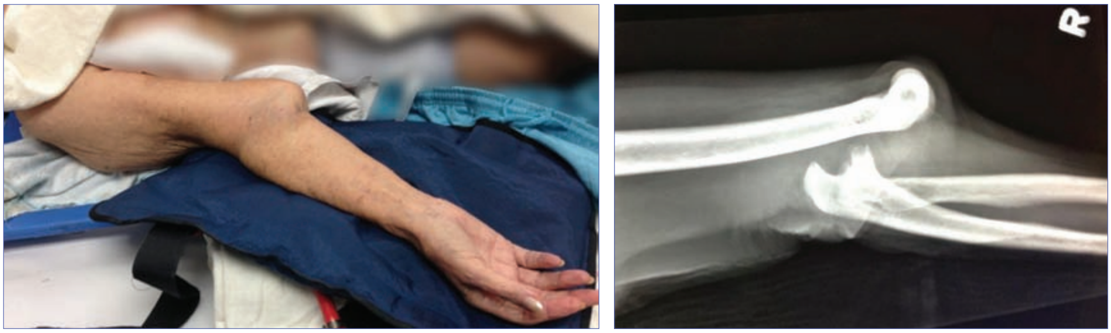


FIGURE 52.6 Posterior elbow dislocation and X-ray. Notice the posterior prominent olecranon inducing a divot-like defect in the posterior humerus.

Anterior

- Caused by a direct posterior blow to a flexed elbow
- Arm is extended
- Upper arm appears shortened
- Forearm is elongated and supinated
- Essentially no ROM
- Triceps tendon may be disrupted
- Pain
- Swelling
  - Highest incidence of brachial artery disruption, especially with an associated fracture (**FIGURE 52.7**).

Medial/Lateral/Divergent

- These types of dislocations are rare with the mechanism of injury related to significant high-energy trauma to the elbow (**FIGURE 52.8**). The proximal radioulnar joint is disrupted as the distal part of the humerus is driven between the radius and ulna, and the forearm dislocates posteriorly.
- Assessment for brachial artery disruption and/or entrapment of the ulnar (especially with associated medial epicondyle fractures) and median nerves needs rapid evaluation (**FIGURE 52.7**).

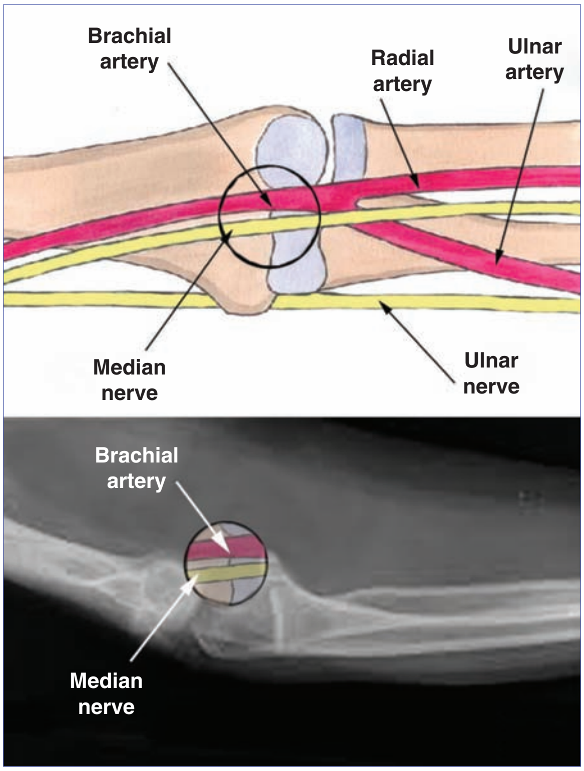


FIGURE 52.7 Anterior elbow dislocation.

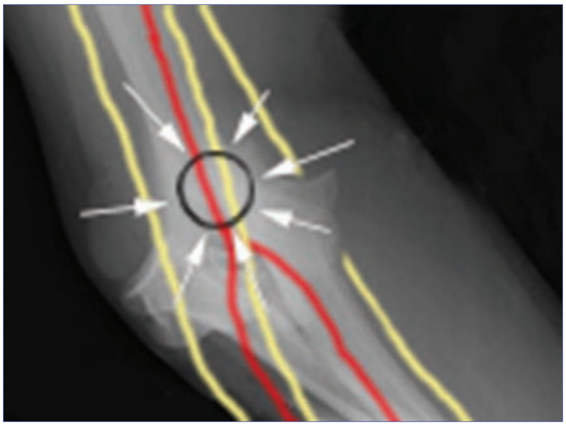


FIGURE 52.8 X-ray of divergent elbow dislocation with potential brachial/radial/ulnar artery and median/ulnar nerve injury.

TREATMENT

Initial evaluation should focus on a thorough physical exam:

- Assess for neurovascular compromise
  - Brachial artery and distal branches, radial and ulnar arteries
    - Most serious complication of elbow dislocation
    - Can have delayed onset due to inflammation and swelling
  - Neuropraxia of the ulnar and median nerves
    - *Ulnar nerve injuries are usually transient and are reported in 14% of cases.*
    - *Considering their location, median nerve injuries are associated with brachial artery injuries.*

Imaging

- PA and lateral radiographs should be performed prior to reductions in order to document possible fractures and confirm clinical diagnosis.
  - Usually occur at
    - Radial head
    - Coronoid process
    - Olecranon
    - Humeral condyles
    - Capitellum
- If x-rays are inconclusive or strong suspicion for fracture exists, consider CT scan for increased sensitivity (**FIGURE 52.9**).

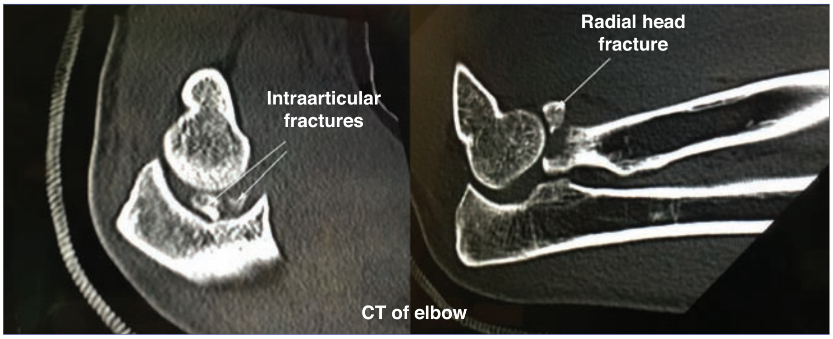


FIGURE 52.9 Complex elbow dislocation with intraarticular fracture fragment hindering successful reduction and not visualized on x-ray.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Open dislocations
  - Orthopedic consultation to perform copious irrigation and take patient to the operating room.
- Fracture
- Incongruent reduction
  - Can be secondary to soft-tissue interposition and/or loose body
  - May require surgical intervention to resolve

PROCEDURE PREPARATION

Administer intravenous/intramuscular analgesics prior to radiographs.

- Prepare for procedural sedation
  - Cardiac monitor
  - Pulse oximeter
  - End-tidal CO_2
  - Assistant
  - Requires potent and short-acting medication
    - Propofol
    - Ketamine
    - Etomidate
    - Nitrous oxide

PROCEDURE

Fundamental to the successful realignment of all reductions (displaced fractures as well) is the notion that the clinician cannot simply apply traction to the bones that are displaced. This may not only lead to multiple unsuccessful reduction attempts and frustration, but may also lead to iatrogenic fracture(s). The clinician must understand and conceptualize the need to apply the following three forces to all such cases:

- Exaggeration
  - Actually amplify and make the dislocation worse
    - Causes the bone to clear any potential soft-tissue or bony tuberosity
- Distraction
- Traction

Posterior Reduction

PRONE METHOD

- Position patient in the prone position on the stretcher, ensuring their head is turned and airway is not compromised.
- Patient's arm is hung over the edge of the stretcher or padded side rail in the flexed position (**FIGURE 52.10**).
- Distal pressure is applied via the clinician's two thumbs to the posterior aspect of the palpable and free olecranon (**VIDEO 52.1**).
- Avoid putting pressure on the antecubital fossa as nerves and vasculature are vulnerable in this area.
- The assistant uses both hands and grasps the forearm and applies downward pressure.
- Slight flexion of the elbow may help relax/disengage the triceps muscle.
- Successful reduction is either heard or felt with an obvious "clunk."
- Flex the patient's elbow 90 degrees to ensure successful reduction.

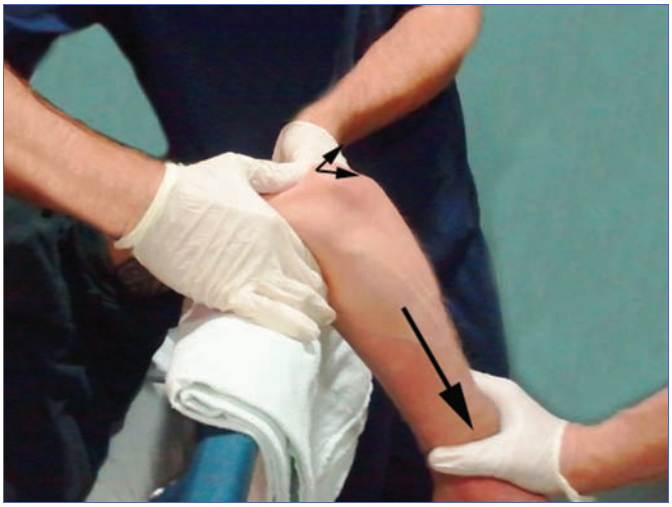
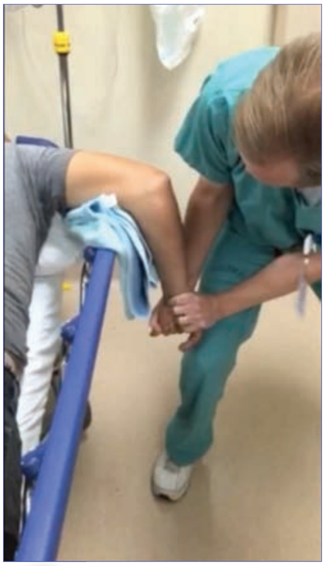


FIGURE 52.10 Prone method for posterior elbow reduction.



VIDEO 52.1 Prone method for posterior elbow reduction. Note there should be an assistant applying distal pressure on the olecranon.

TRADITIONAL TRACTION METHOD

- Place the patient in the prone position with the assistant stabilizing the humerus and providing countertraction.
- With one hand, grasp the affected wrist with the forearm in supination.
- Apply an exaggeration of the injury, distraction, and slow and steady in-line traction.
- Manipulate the olecranon with the other hand to aid in the reduction.
- Slight flexion of the elbow may help relax/disengage the triceps muscle.
- Successful reduction is either heard or felt with an obvious "clunk."
- Flex the patient's elbow 90 degrees to ensure successful reduction.

ONE-PROVIDER METHOD

- Lay the patient supine with the affected arm across the chest and the olecranon pointing up.
- With one hand, grasp the wrist of the affected arm and pull traction (**FIGURE 52.11**).
- With the other hand, stabilize the distal humerus and, if possible, manipulate the olecranon.
- The patient may assist by resisting traction.

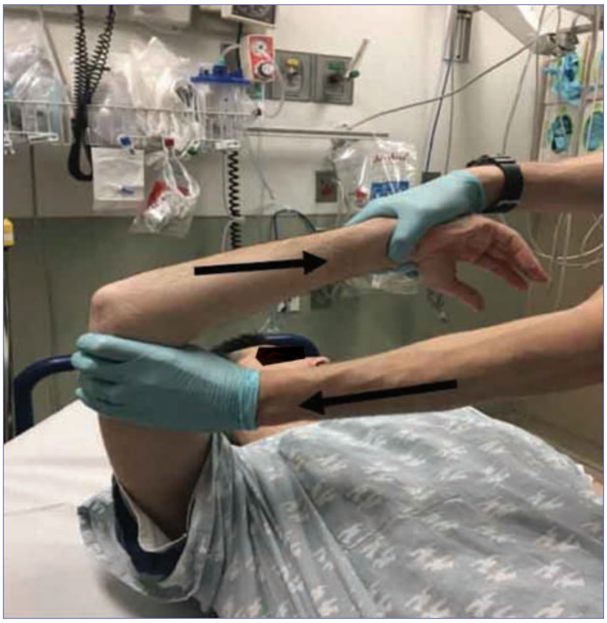


FIGURE 52.11 One-provider reduction method for posterior elbow dislocation.

Anterior Reduction

- Patient lies in the supine position.
- An assistant provides countertraction by grasping the humerus with both hands.
- The clinician holds the forearm with both hands and applies an exaggeration of the injury, distraction, and slow and steady in-line traction.
- Flex the patient's elbow 90 degrees to ensure successful reduction.

POSTPROCEDURE CONSIDERATIONS

- After reduction, reassess for any neurovascular abnormalities.
  - Immediate surgical consultation should be obtained as well as emergency arteriography if a pulse is diminished or absent.
- Order bedside postreduction x-ray (**FIGURE 52.12**).
- Put the elbow through gentle ROM.
  - Note that the elbow is often unstable in extension.
- Immobilize the elbow with a long arm splint with 90-degree flexion with slight pronation of the forearm.
  - After splint placement, reassess for any neurovascular abnormalities. Another reassessment after a period of observation of 2 to 3 hours is appropriate, as delayed vascular compromise may occur.
- Patients benefit from short-term immobilization of 5 to 10 days and early ROM therapy.
- Josefsson et al. (1984) carried out two studies: a retrospective cohort study and a randomized trial comparing surgical and nonsurgical treatment of ligamentous injuries after simple elbow dislocation; at more than 12-months' follow-up, there was no statistically significant difference between the two groups in terms of elbow ROM in either study.

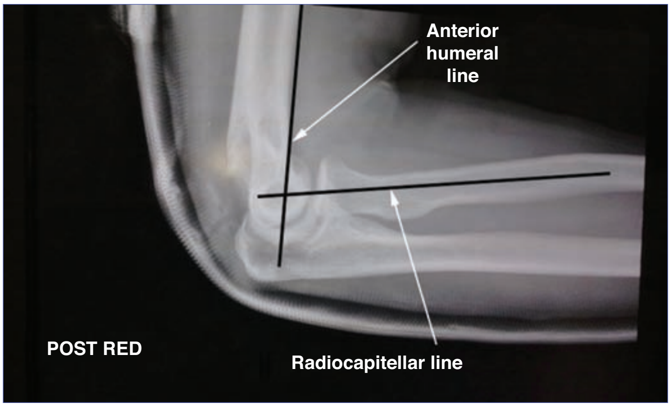


FIGURE 52.12 Postreduction x-ray with normal alignment; note that the humeral olecranon fossa and radiocapitellar lines are intact.

EDUCATIONAL POINTS

- Open and anterior dislocations are associated with disruption of the brachial artery and/or injury to the median nerve and warrant a detailed neurovascular exam and orthopedic consultation.
- Significant soft-tissue swelling and/or hematoma formation or those who have vascular/neurologic compromise should have immediate orthopedic/vascular surgery consultation.
- Evaluation and documentation of the brachial artery and neurologic examination of the median/ulnar nerve prior to and after closed reduction are paramount.
- All dislocations are attended by at least some disruption of the joint capsule (LCL and/or MCL), and, depending on the degree of this disturbance, coupled with any associated fracture(s), future stability/instability can be predicted.
- Complex elbow dislocation is dislocation when a fracture is present. CT scans are increasingly used to diagnose the degree and location of the fracture.
- FOOSH type of injury accounts for the majority of elbow dislocations.
- Short-term (5–10 days) immobilization is recommended postreduction; patients should begin ROM exercises under the supervision of a therapist after about 1 week from injury.
- The MCL complex plays a vital role in primary stability of the elbow in valgus and posteromedial directions and as a rule is disrupted in all posterior/posterior–lateral dislocations, which comprise the majority of elbow dislocations.

COMPLICATIONS

Valgus Instability

- Patients will show a variable amount of MCL laxity, which correlates with a worse clinical and radiographic result.
- To minimize the stress on the MCL, the forearm should be placed in full pronation, which reduces the chances of recurrent posterolateral subluxation.
- Detrimental effects of prolonged immobilization:
  - Flexion contractures
  - Enhanced perception of pain
  - Increased duration of disability
- On long-term follow-up in simple closed reductions, Josefsson et al. (n.d.) have shown that one-third of patients had what was described as “moderate loss of extension” at the elbow.
- Recurrent dislocation is extremely rare.
- Throughout the immobilization phase, wrist and shoulder function should be maintained through ROM and strengthening exercises.
- In anterior and divergent dislocations especially, compartment syndrome may occur after the acute phase of treatment and warrants observation.
  - Multiple evaluations of the neurovascular status to the anterior forearm compartment are needed.
    - Swelling
    - Pain
    - Passive finger flexion

PEARLS

- Exaggeration, distraction, and traction are the rules for successful elbow joint reduction coupled with proper sedation/analgesia.
- Open and anterior dislocations are associated with brachial artery injury.
- Anterior dislocations are rare and typically require orthopedic consultation, as they are associated with brachial artery injuries.
- Complex elbow dislocations require orthopedic consultation.
- Early analgesics are a must and should be given prior to radiographs.
- Procedural sedation should be used unless contraindicated.
- Neurovascular examination of ulnar/median nerves and the brachial artery should occur at the prereduction, postreduction, and the postsplint phases and after a period of observation.

- Consider CT scan in instances in which a reduction cannot occur or be maintained in order to detect subtle intraarticular fracture(s).
- Chronic pain and stiffness are common long-term sequelae.
- Neurovascular compromise is not a contraindication to reduction, but rather an indication for reduction as soon as possible as reduction may correct neurovascular compromise.
- Normal radiocapitellar alignment should be seen on postreduction films to demonstrate adequate reduction.
- Most patients do well after a closed reduction; less than 10% will need surgical intervention.

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CHAPTER

53

Procedures for Digit Dislocation

Maura Sammon and Keith Lafferty

BACKGROUND

Due to the considerable exposure of the hand, especially among athletes, injuries are common. A basic review of the articular anatomy is key to understanding and treating these common injuries.

The anatomic structure of the proximal interphalangeal (PIP), distal interphalangeal (DIP), and metacarpophalangeal (MCP) joints are fundamentally the same. However, the MCP joint is condyloid in shape, allowing some abduction and adduction, whereas the PIP/DIP joints are more hinge or tongue-and-groove joints that do not allow lateral movement. The ligamentous supports of the MCP joints are thicker and are also reinforced by the deep transverse metacarpal ligament and hence are much less prone to injury.

The MCP and interphalangeal (IP) joints are stabilized laterally by the strong collateral ligaments, dorsally by the extensor hood complex, and volarly by the volar plate (**FIGURE 53.1**). The extensor hood complex helps prevent volar dislocation. Because of this lateral–volar support, dorsal dislocations are more common and also, by definition, imply a disruption of the volar plate. ***Lateral dislocations have a disruption of one of the collateral ligaments and at least a partial tear of the volar plate. Dislocations are more common at the PIP joint than at the DIP joint due to the additional stability of the flexor and extensor tendon insertions at the distal phalanx.***

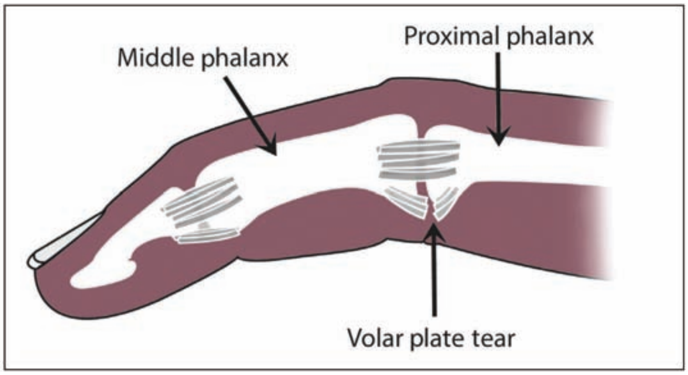

FIGURE 53.1 Volar and collateral ligament anatomy.

Classification of dislocated MCP/IP joints is defined as dorsal, volar, or lateral based on the displacement of the distal segment. They are also defined as either simple or complex. Simple dislocation implies that no soft tissue (volar plate or tendon) is interposed or entrapped in the joint, allowing an easy, closed reduction. ***The term* complex dislocation *implies soft-tissue entrapment in the joint, making a closed reduction difficult with probable need for operative repair.***

IP dislocations are common, with dorsal PIP dislocations being the most common hand luxation in adults. ***The majority of DIP dislocations are dorsal and may be associated with a flexor digitorum superficialis avulsion injury***. Volar dislocations often involve rupture of the collateral ligaments, the volar plate, and the central slip of the extensor mechanism. They often involve soft-tissue interposition and are thus often irreducible by closed reduction. Prompt repair of these injuries is important because they may lead to a ***boutonnière deformity*** if left untreated.

- Volar dislocations may lead to a future boutonnière deformity.

The first MCP joint is much more susceptible to injury than the other MCP joints and it is essential to consider injury to the ulnar collateral ligament (UCL). This is known as a *gamekeeper's thumb*. The integrity of this ligament is crucial for proper thumb opposition and normal grasping features of the hand. The patient may present with only

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localized tenderness along the UCL at the first MCP joint. Associated volar plate injuries are common. Early recognition through ulnar collateral stress testing is necessary to identify such an injury. Proper immobilization and immediate orthopedic follow-up decreases morbidity.

PATIENT PRESENTATION

Symptoms present as follows:

- Acute pain
- Swelling
- Deformity (**FIGURE 53.2**)
- Decreased range of motion

TREATMENT

Anesthesia may be performed using either a digital or metacarpal block for DIP/PIP dislocations or a wrist block for MCP dislocations. Closed reduction can be accomplished in most cases. Radiographs, before and after reduction, are used to identify fractures and confirm adequate reduction (**FIGURE 53.3**). The proper use of a methodical technique is paramount for successful reduction and, furthermore, to avoid causing a simple dislocation becoming a complex one.

Open dislocations should be referred to orthopedics for copious irrigation and repair.

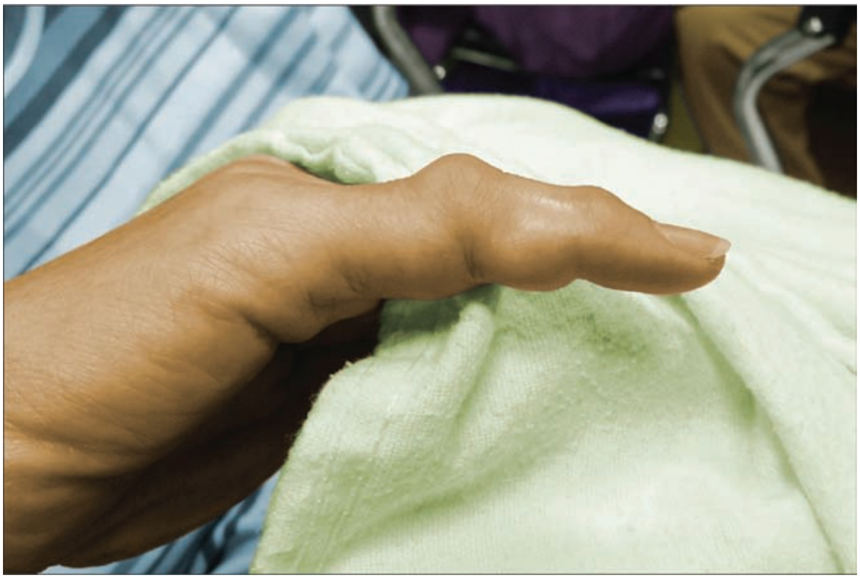


FIGURE 53.2 Dorsal dislocation—of the PIP joint.

PIP, proximal interphalangeal.

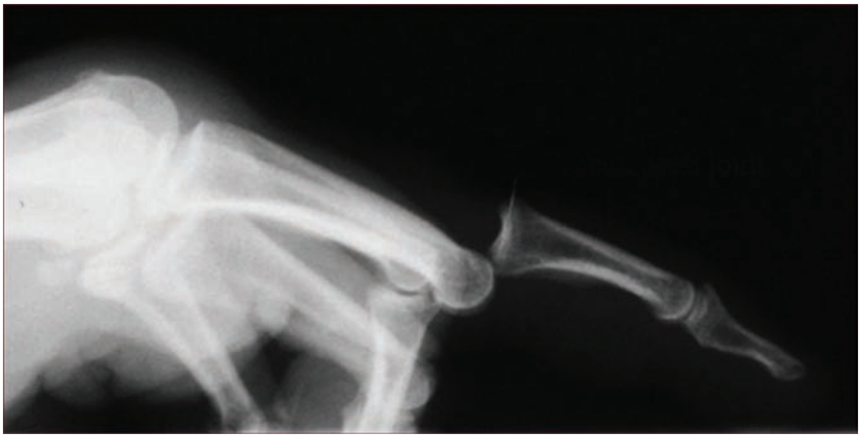


FIGURE 53.3 X-ray of dorsal PIP joint dislocation.

PIP, proximal interphalangeal.

SPECIAL CONSIDERATIONS

Consultation with a hand surgeon should be considered early in the management of digit injuries with the following:

- Digital nerve compromise
- Associated fracture
- Open joint dislocation
- Ligamentous or volar plate rupture

Mallet Finger

Mallet finger is caused by forced flexion of an extended finger when struck by an object and is also known as "baseball finger." The joint appears normal on passive extension; however, the patient cannot extend the distal phalynx. The injury is a rupture of the extensor tendon (terminal extension of the dorsal mechanism, which is a complex crossing of fibers that cross the PIP and MCP joints) with or without avulsion of a small piece of bone.

- Nondisplaced avulsion fractures of less than 30% of the articular surface are believed to be stable injuries.
- This injury must be recognized and properly splinted (**FIGURE 53.4**) or, over time, a permanent hook-like deformity will lead to a permanent *swan-neck deformity* (**FIGURE 53.5**).
  - With a disruption of the dorsal mechanism at the DIP joint, the entire power of extension is directed to the PIP joint.
  - Over time, and especially if the volar plate is lax, this concentrated extension force results in PIP joint hyperextension and a swan-neck deformity (i.e., the DIP joint rests in an abnormally flexed position and the PIP joint rests in a hyperextended position); therefore, the mistreatment of a mallet injury may preclude development of swan-neck deformity.

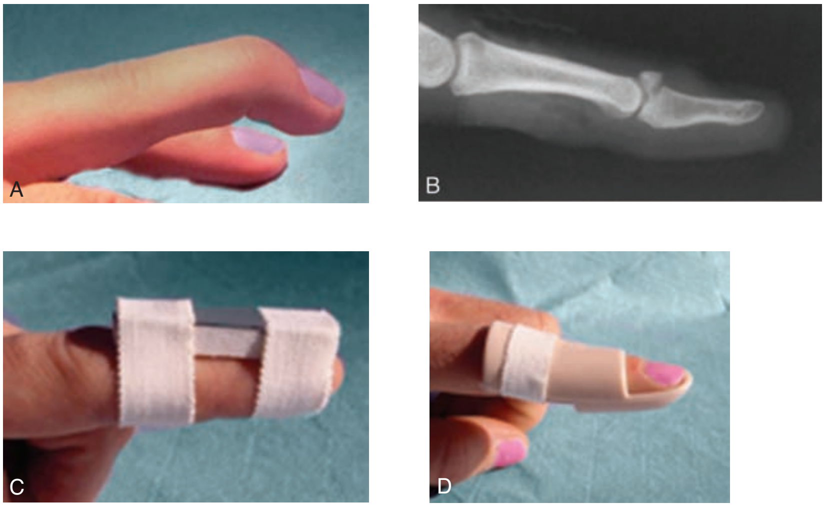


FIGURE 53.4 (A) Mallet finger. (B) Associated fracture at the site of the distal extensor tendon insertion. (C) and (D) Varying splints in full extension.

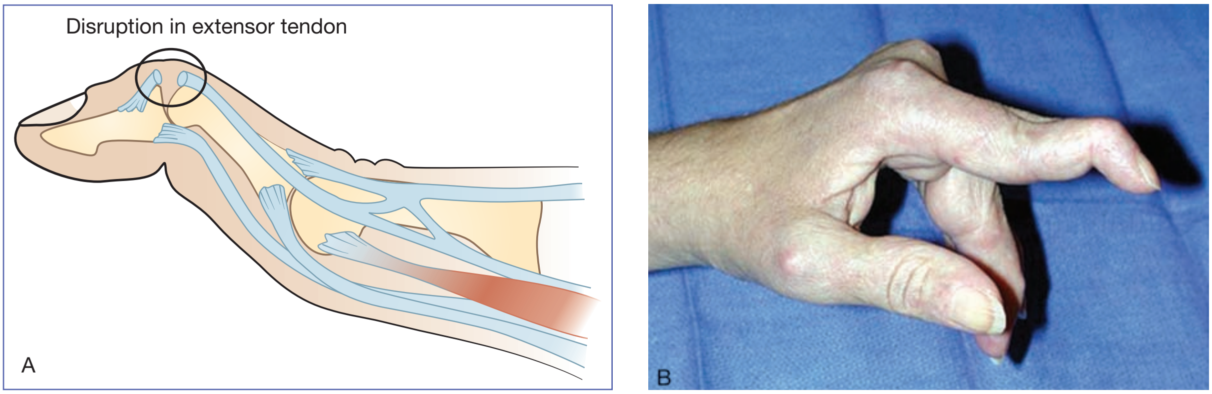


FIGURE 53.5 (A) Illustration and (B) photograph depicting swan-neck deformity.

Source: (B) Reproduced with permission from Henry, G. I., Molnar, J. A. (2020). Extensor tendon lacerations. *Medscape Drugs & Diseases*. Retrieved from https://emedicine.medscape.com/article/1286225-overview

Thumb MCP Dislocation

The MCP joint in the thumb is similar to the MCP joints in the fingers but has inherent stability secondary to a stronger volar plate and collateral ligaments. IP dislocations do occur in the thumb but are much rarer compared to the more common MCP joint (in the other fingers, IP dislocations are more common than those of the MCP). However, because of its vulnerability, especially in athletes, the MCP joint is subject to dislocations. Dorsal MCP dislocations are the rule. In fact, a rare volar dislocation is associated with tears of both dorsal capsule ligaments and the extensor pollicis brevis (EPB); therefore, volar dislocations are often treated with surgical repair of the torn structures, and closed reduction is rarely achieved with adequate postreduction stability (**FIGURE 53.6**).

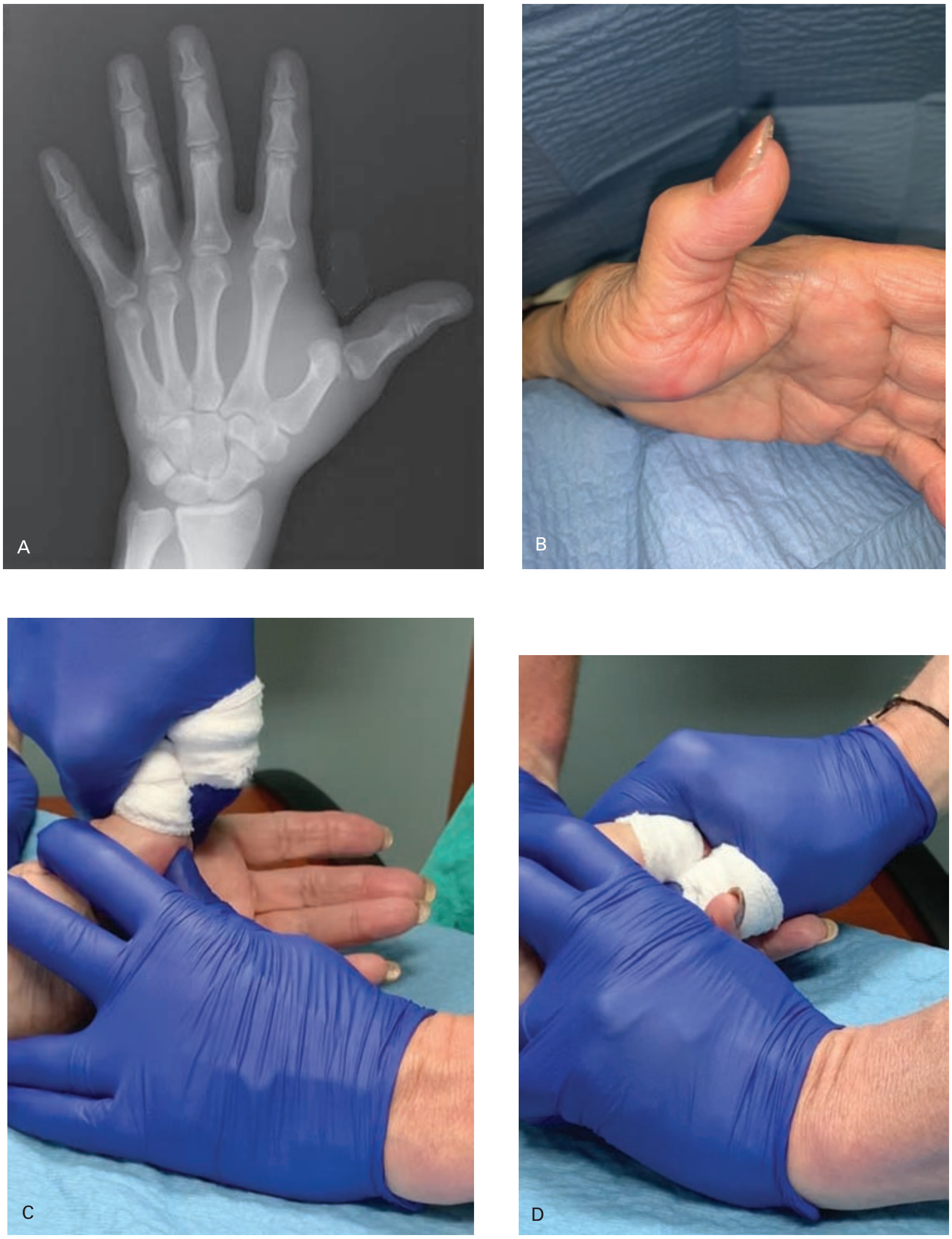


FIGURE 53.6 (A) X-ray MCP dislocation of thumb. (B) Although the technique is similar to other MCP joint reductions, it can be more challenging to relocate. (C) Using rubber gloves and/or gauze, a firm grasp of the thumb is key. (D) Besides exercising the normal technique of exaggeration, distraction, and traction, one should also apply firm and constant pressure to the base of the proximal phalynx; finally, flex the MCP joint to complete the procedure.

MCP, metacarpophalangeal.

Collateral Ligament Rupture

A ***gamekeeper's/skier's thumb*** is an injury/rupture of the UCL at the MCP joint secondary to a lateral/abducting force in this area; it is often seen in skiers falling on their held ski pole, causing rupture of the ulnar collateral ligament. The normal function of this joint is important for grasping objects. A high index of suspicion is needed as these injuries are often missed as the patient presents with a reduced thumb and isolated pain at the ulnar MCP area; as such, all patients with this presentation must be assumed to have an injury, and hence a thumb spica is in order. Even if collateral joint testing is negative (**FIGURE 53.7**), a strain of this ligament is probable, so splinting and orthopedic follow-up are mandatory. X-rays and point-of-care ultrasound (POCUS) may demonstrate an avulsion-type fracture. Ebrahim et al. (2006) published an excellent review on using POCUS for diagnosing UCL injuries and full tears (**FIGURE 53.8**).

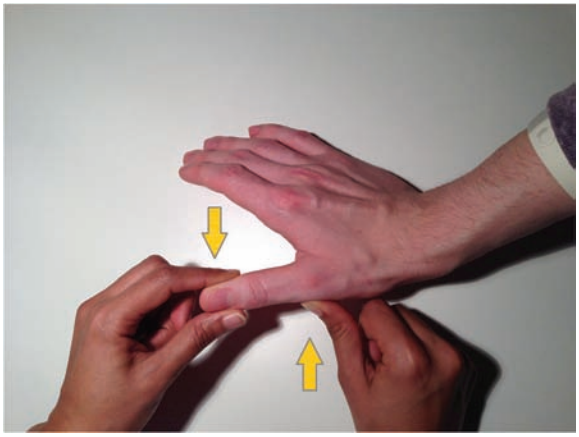


FIGURE 53.7 Ulnar collateral ligament stress testing.

Source: Mahajan, M., & Rhemrev, S. J. (2013). Rupture of the ulnar collateral ligament of the thumb—A review. *International Journal of Emergency Medicine, 6*, 31. Retrieved from https://intjem.biomedcentral.com/articles/10.1186/1865-1380-6-31

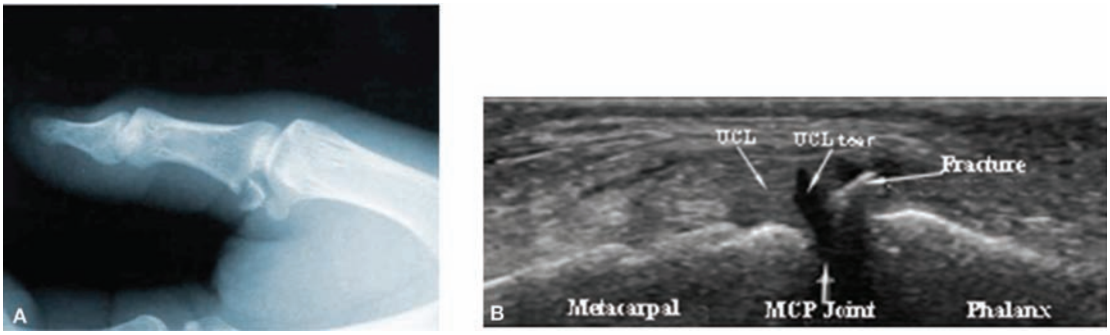


FIGURE 53.8 (A) Gamekeeper's thumb injury with an avulsion fracture. (B) POCUS via a high-frequency probe detecting not only the avulsion fracture but the torn UCL as well represented by the hypoechoic area over the UCL. Note the UCL usually tears near the metacarpal insertion site. POCUS is more dynamic and less time-consuming and may be easier to perform.

MCP, metacarpal; POCUS, point-of-care ultrasound; UCL, ulnar collateral ligament.

PROCEDURE PREPARATION

- Patient should be comfortable with the dislocated joint well exposed
- Local anesthetic agent
- Rubber gloves (grip)
- Finger splint, thumb spica, or buddy tape

PROCEDURE

PIP/DIP Closed Reduction

DORSAL DISLOCATION

As previously stated, PIP/DIP dorsal dislocations are the most common (**FIGURE 53.9**). They usually occur secondary to an axial load to the end of the finger, coupled with hyperextension (football catch "jams" finger). Disruption of the volar plate usually occurs. An associated fracture may

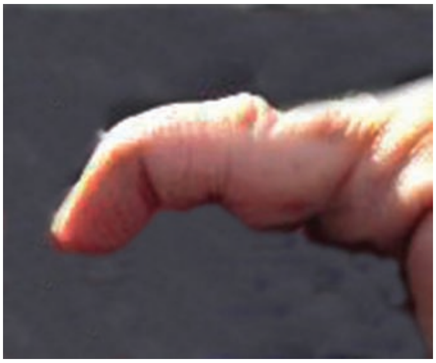


FIGURE 53.9 Dorsal PIP dislocation of the finger.

PIP, proximal interphalangeal.

occur and, if it encompasses 33% of the joint surface, closed reduction will be unstable because the collateral ligament is attached to the bony fragment; surgical repair is then necessary.

VOLAR DISLOCATION

Volar dislocations are uncommon and always involve a disruption of the central slip of the extensor tendons (**FIGURE 53.10**). Because of this disruption, after reduction one must treat using extension; otherwise, a boutonnière deformity may ensue (**FIGURE 53.11**). Left untreated (not splinting in extension), an injury to the central slip can result in this deformity within 2 to 3 weeks.

This injury still may need surgical repair of the violated central extensor tendon; therefore, all these injuries warrant orthopedic follow-up (**see TABLE 53.1** for differences in dorsal versus volar IP reductions; **FIGURE 53.12**, **VIDEO 53.1**).

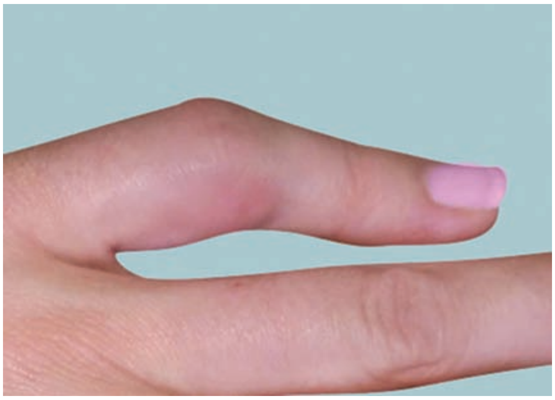


FIGURE 53.10 Volar PIP dislocation of the finger.

Source: Reproduced with permission from RehabMyPatient. Retrieved from https://www.rehabmypatient.com/hand-fingers-thumb/finger-proximal-interphalangeal-pip-joint-dislocation

PIP, proximal interphalangeal.

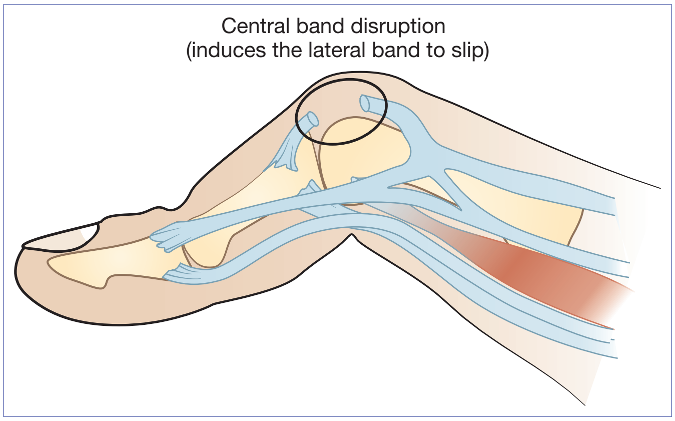


FIGURE 53.11 Boutonnière deformity. Note there is a pathologic flexion at the PIP joint and hyperextension at the DIP joint. This is secondary to disruption of the central slip of the extensor tendon as it slides volarly at the PIP joint and, paradoxically, causes flexion. The joints still attach to the distal phalanx as part of the distal extensor tendon; hence, hyper-extension occurs at the DIP joint.

DIP, distal interphalangeal; PIP, proximal interphalangeal.

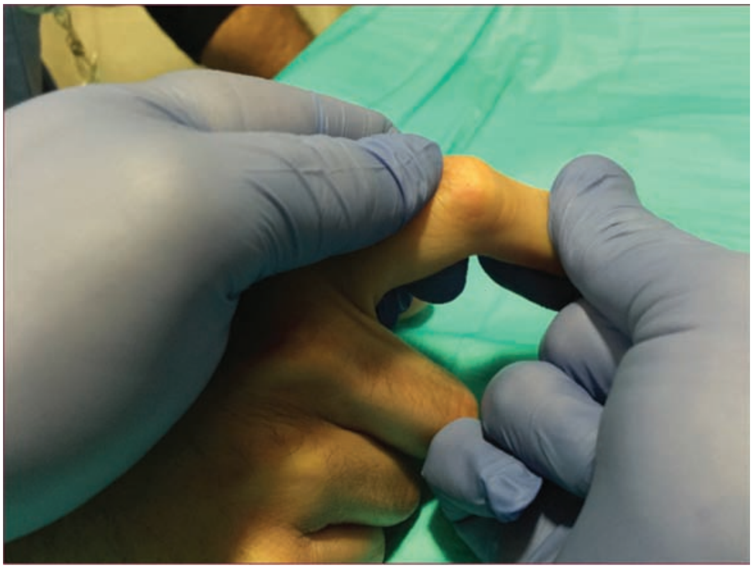
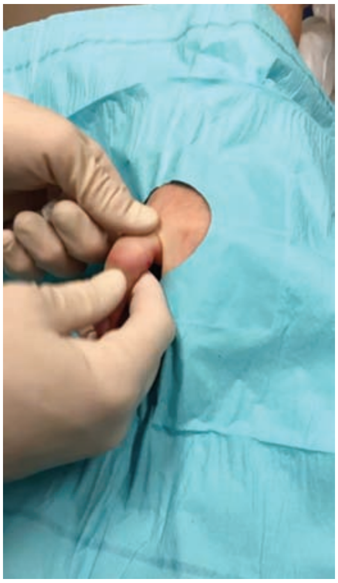


FIGURE 53.12 Closed reduction of a volar PIP joint dislocation. Note that this is less common than dorsal IP joint dislocations.

IP, interphalangeal; PIP, proximal interphalangeal.



VIDEO 53.1 Volar proximal interphalangeal reduction.

TABLE 53.1 Dorsal IP Reduction and Volar IP Reduction

Dorsal Reduction	Volar Reduction
Exaggerate the deformity	Exaggerate the deformity
Hyperextend	Hyperflex
Apply longitudinal traction	Apply longitudinal traction
Apply dorsal pressure	Apply volar pressure

IP, interphalangeal.

LATERAL DISLOCATION

Lateral PIP/DIP are often reduced in the field. Collateral ligament tears are the rule. History can often elicit the finger pointing in a precarious direction. The injury can be detected by applying ulnar and radial stress to the PIP joint. If still dislocated, recreate the injury and then apply longitudinal traction to reduce the dislocation. Reduction follows the dictum of exaggeration, distraction, and traction.

MCP Closed Reduction

Dimpling on the palmar surface usually represents interposed tissue and hence a complex dislocation. ***This is a more difficult procedure compared to IP reduction and has a higher chance of complex dislocation***. If an improper method is used, the chance of converting a simple dislocation into a complex dislocation increases.

- Flex wrist and the MCP joint in order to relax the stabilizing effects of the flexor tendons.
- Extend and apply longitudinal traction.
- Apply dorsal pressure.
- Unlike IP reductions, excessive hyperextension and excessive longitudinal traction should be avoided (**FIGURE 53.13**).

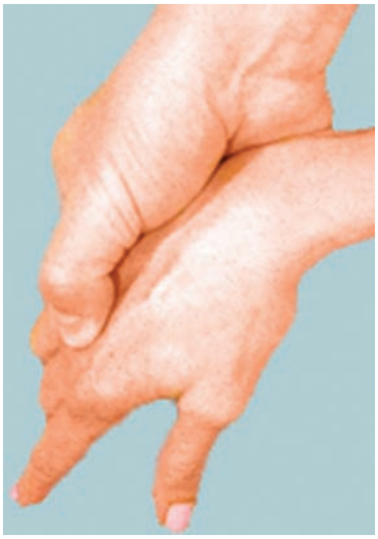


FIGURE 53.13 MCP reduction.

MCP, metacarpophalangeal.

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POSTPROCEDURE CONSIDERATIONS

- Postreduction radiographs are not necessary for uncomplicated reductions.
- DIP splints are applied with the DIP and PIP joint in 20 degrees of flexion.
- PIP reductions should be splinted or buddy taped for 2 to 3 weeks.
- Both DIP and PIP finger reductions can be splinted or buddy taped with angles above treatment for 10 to 14 days.
- MCP dislocations are treated with a thumb spica in 20 degrees of flexion for 4 weeks with close orthopedic follow-up.
- Other MCP joint reductions are treated in flexion using a volar splint for 3 to 4 weeks.
- Treatment of toe reductions is with buddy tape and a walking shoe for 2 to 3 weeks for the first toe and 10 to 14 days for the lesser toes.

EDUCATIONAL POINTS

- Follow-up with a hand surgeon should be done if successful reduction is unable to be accomplished.

COMPLICATIONS

- Fractures
- Conversion of a simple dislocation into a complex one
    - Remember to use gentle, steady forces and always exaggerate the injury first, followed by distraction and then traction.

PEARLS

- Always remove rings from patients.
- Volar dislocations are rare and often require operative repair.
- Avoid long-term immobilization to eliminate the possible sequelae of joint stiffness and loss of flexion.
- A firm grip can be ensured if the provider wears a tight rubber glove.
- On reduction, always exaggerate the deformity first in order to lessen further injury and maximize successful reduction.
- Because extrinsic flexors of both IP joints are 4 times stronger than their extensor counterparts, proper range of motion is mandatory in postreduction care to prevent flexion contractures.
- Volar dislocations may lead to a future boutonnière deformity.
- The mistreatment of a mallet injury may preclude development of swan-neck deformity.
- In the context of the physical examination of a possible UCL injury, POCUS is an underused tool because it is potentially an adjunct to the clinical examination in the appropriate setting.

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CHAPTER 54

Procedures for Hip Dislocation

Keith Lafferty, Vince Sperandeo, and Michael Farney

BACKGROUND

The femoroacetabular joint is one of two ball-and-socket joints in the body, with the other being the glenohumeral joint. The hip is the larger of the two and represents 5% of all joint dislocations. The acetabulum of the pelvis creates the socket and the femoral head of the femur creates the ball. This allows the femur to rotate freely through a 360-degree circle and to swivel around its axis 90 degrees.

Traumatic Native Hip Dislocations

A high volume of energy is required to induce traumatic native hip dislocations. This is secondary to the compact nature of the femoroacetabular joint, in which the femoral head is situated deep within the acetabulum. There is a labrum that is strong, dense, and encloxsed; generous ligamentous support; and ample support from surrounding muscle (**FIGURE 54.1**). For these reasons, these dislocations are often associated with other fractures and potential coincident life-threatening injuries that may take precedence in resuscitation. Not surprising, the physical findings of a hip dislocation may be overlooked on initial resuscitation of a patient with trauma. ***In the traumatic dislocations of native hips, up to 95% of these patients have other associated traumatic injuries, including 88% having accompanying fractures***. A thorough physical exam is necessary. Leading mechanisms of hip luxation include frontal motor vehicle collisions (MVCs; 70%), auto versus pedestrian accidents, major falls from heights, and extreme contact sports. ***The amount of force required to dislocate a native hip is substantial and the potential for coexisting injuries warrants hospitalization in all patients.*** This is not the case, however, for prosthetic hip dislocations, as is discussed later.

All acute hip dislocations require rapid diagnosis and reduction to prevent significant morbidity and associated long-term complications.

- ***Among the most serious complications is that of avascular necrosis (AVN), reported in as many as 15% of cases.***
- The blood supply to the femoral head is somewhat precarious and any disruption may result in rapid ischemia and necrosis of marrow and osteocytes in as few as 6 hours.
- Reductions must occur promptly because of this.

The arterial supply to the femoral head is principally provided by the deep branch of the medial femoral circumflex artery, located

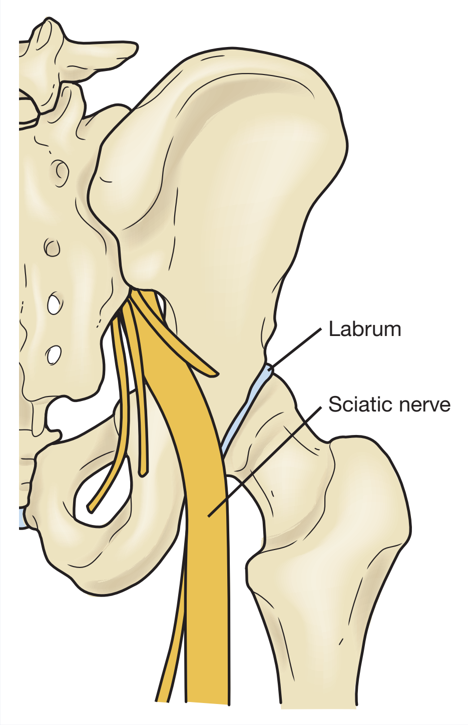


FIGURE 54.1 Hip anatomy with sciatic nerve.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

near the base of the femoral neck, as well as its many branches, which ascend to perfuse the femoral head (**FIGURE 54.2**). ***This arterial supply is well affixed to the femoral neck and is easily damaged with any displaced femoral neck fracture***.

- The incidence of subsequent AVN of the femoral head is a time-dependent phenomenon and is most likely to occur if relocation is delayed beyond 6 hours (excluding prosthetic hips of course).
- Mehlman et al. (2000) demonstrated a 20-fold increased risk of developing AVN in pediatric traumatic hip dislocations if the reduction was delayed 6 or more hours.

Other long-term sequelae include:

- Sciatic/peroneal nerve neuropraxia
- Osteoarthritis
- Heterotopic bone deposition
  - Process by which bone tissue forms outside of the skeleton after traumatic long-bone injury; it may become symptomatic.

Anatomy

The femoral head is deeply seated in the acetabulum. The ball-and-socket joint, along with ligamentous attachments, the labrum, and strong musculature of the upper thigh and gluteal region, provides joint stability. The sciatic nerve rests just behind the femoroacetabular joint and is at risk for injury following posterior hip dislocation (PHD; **see FIGURE 54.1** and **54.3**).

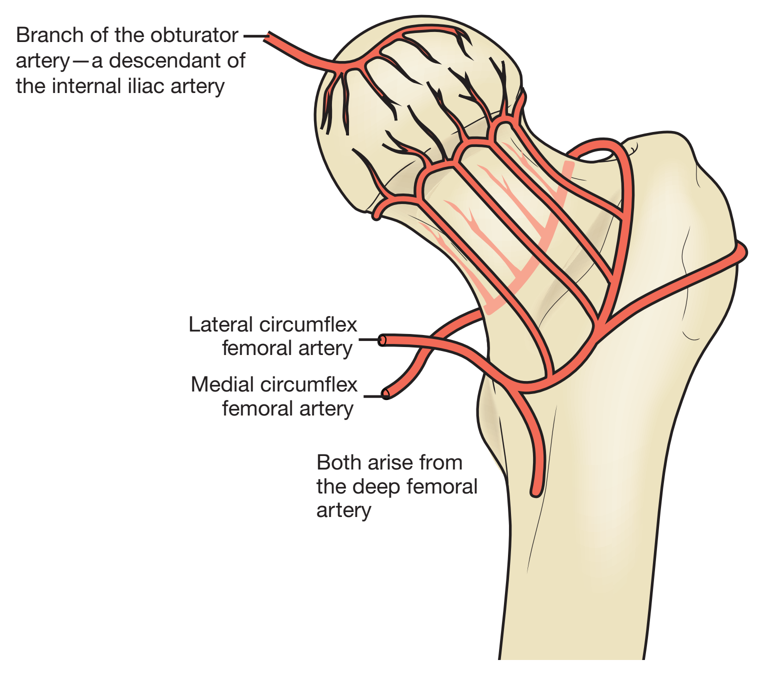

Branch of the obturator artery—a descendant of the internal iliac artery
Lateral circumflex femoral artery
Medial circumflex femoral artery
Both arise from the deep femoral artery

FIGURE 54.2 Arterial supply to the femoral head.

Prosthetic Hip Dislocations

A recent study (Wolford, Palso, & Bercovitz, 2015) has shown that from the years 2000 to 2010, the number of annual total hip arthroplasty (THA) procedures has more than doubled to 310,800. The number grew by 92% among those 75 and older, and increased 205% in those aged 45 to 54. During the next 15 years, the number of THAs is expected to increase to 572,000 cases per year (Kurtz, Ong, Lau, Mowat, & Halpern, 2007). With this rapid increase in the number of THAs being performed, the number of dislocations no doubt will also increase.

These inherently less stable joints require minimal and trivial forces, such as crossing one's leg, arising from a seated position, or rolling over in bed, to effect dislocation. Prosthetic hip dislocations are reported in 0.2% to 10% of primary THA procedures.

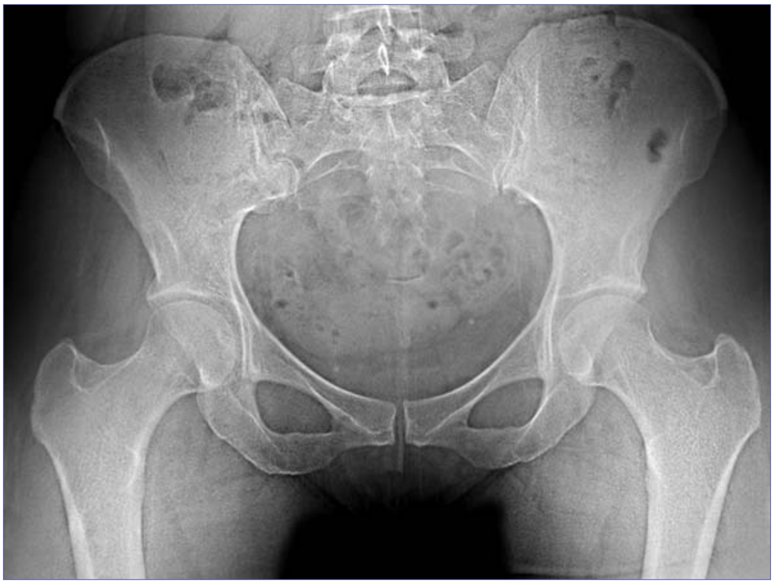


FIGURE 54.3 Normal anterior–posterior pelvis x-ray.

In accordance, recurrent prosthetic hip dislocations may require a revision of the prosthesis to prevent future recurrences. It is unfortunate that upto 28% of these revisions tend to dislocate, with 70% becoming recurrent.

- In these cases, posterior displacement occurs 90% of the time compared to anterior dislocations and is likely to occur in the first 3 to 4 months following THA.

Patients may present up to 10 years after the operation with a nontraumatic hip dislocation. Consultation with the orthopedic surgeon who performed the hip prosthesis should be considered prior to attempting reduction in patients who are still within 3 to 4 months post-THA. Please review **TABLE 54.1** for risk factors for instability following THA.

TABLE 54.1 Risk Factors for Instability Following Total Hip Arthroplasty

Patient Factors	Surgical Factors
Female	Surgical approach
Age >80	Capsular repair
Neuromuscular disorders	Soft-tissue tension
Cognitive disorders	Component malpositioning
Alcoholism	Femoral head size
Abductor weakness	Impingement
Prior hip surgery	Surgeon experience
Patient teaching and compliance	Type of component used

Posterior Hip Dislocations

PHDs account for 90% of all cases. Unrestrained front-seat passengers are especially vulnerable to PHDs secondary to the anatomic positioning of knee flexion and hip flexion/adduction, coupled with a posteriorly displaced force. The more the hip is flexed on impact, the smaller the chance for an associated acetabular fracture. On collision, the flexed knee strikes the dashboard and transmits a forceful axial load along the femoral shaft up the flexed and adducted femur to the femoral head, propelling it posteriorly through the acetabulum (**FIGURE 54.4**).

- Associated fractures of the posterior rim of the acetabulum can occur.
- The sciatic nerve is positioned posteriorly to the acetabulum and thus has the highest incidence of neuropraxia compared to other nerves (**FIGURE 54.5**).
  - The incidence occurs in approximately 10% of adults and 5% of children.

The peroneal branch of the sciatic nerve is most often injured via laceration, stretching, compression, or later becoming encased within heterotopic ossification. A focused neurological exam at the time of injury is extremely important, because if nerve injury is detected, prompt closed reduction must ensue.

- Often, reduction relieves distortion of the nerve from a dislocated femoral head or displaced acetabular fracture, and diminishes long-term sequelae.
  - Full/partial recovery of nerve function occurs in 60% to 70% of patients.

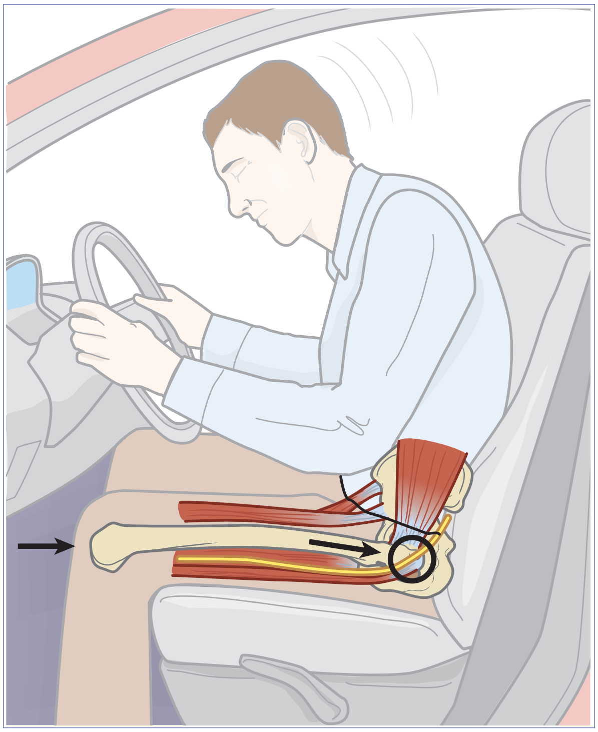


FIGURE 54.4 Posterior hip dislocation via motor vehicle accident.

Anterior Hip Dislocations

Anterior dislocation of the hip (10%) occurs from a direct blow to the posterior aspect of the hip. This is typically from a force applied to an abducted leg that levers the hip anteriorly out of the acetabulum. The hip is forced into abduction and the force pushes the femur medially, while the abduction causes the femoral neck or greater trochanter to lock against the superior segment of the acetabulum. The greater trochanter or femoral neck then acts like a lever, propelling the femoral head out of the acetabulum. A medially directed force then pushes the femoral head through the anterior acetabular capsule.

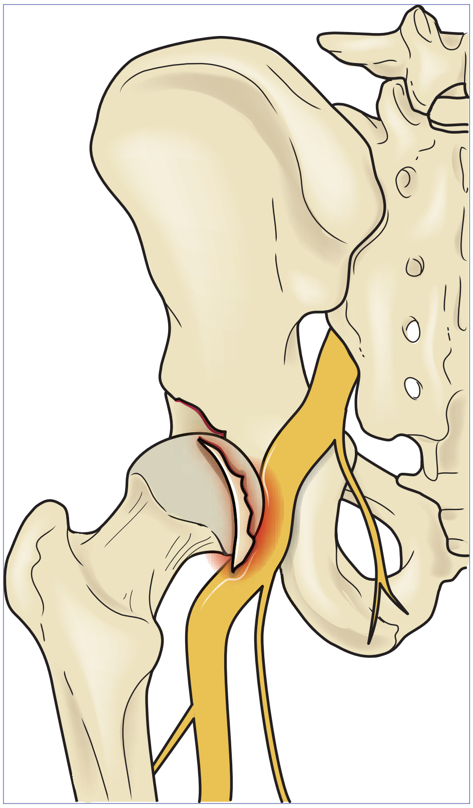


FIGURE 54.5 Sciatic nerve injury secondary to a traumatic posterior hip dislocation. Note associated posterior acetabular rim fracture.

PATIENT PRESENTATION

Patients often present in severe pain associated with native hip dislocations and have a history of extreme mechanisms required to induce such dislocations. A thorough and detailed physical exam must be carried out in order to diagnose coexisting and potentially life-threatening injuries.

Posterior Hip Dislocation

- Leg is shortened, adducted, and internally rotated, with the hip and knee held in slight flexion (**FIGURE 54.6**)
- Acronym "PID"
  - P = Posterior hip dislocation (PHD)
  - I = Internal rotation
  - D = ADduction
- Inability to bear weight
- Signs of a sciatic nerve injury may be present.

Anterior Hip Dislocation

- Leg is externally rotated, abducted, and extended at the hip (**FIGURE 54.7**).
  - The femoral head may be palpated anterior to the pelvis.
  - Signs of injury to the femoral nerve or artery may be present.

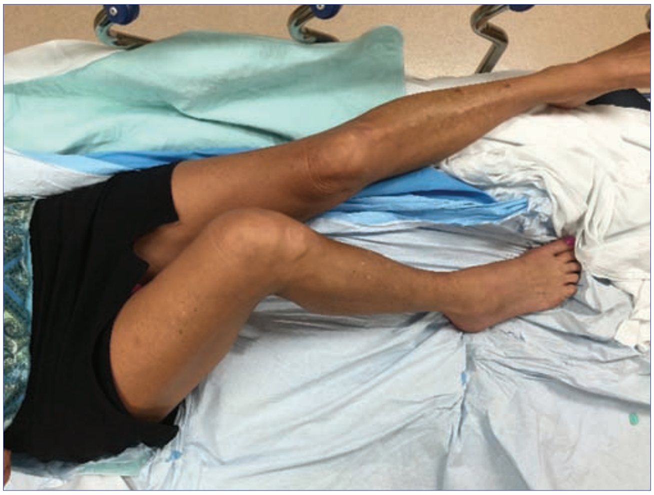


FIGURE 54.6 Posterior hip dislocation—shortening with internal rotation and adduction of the hip.

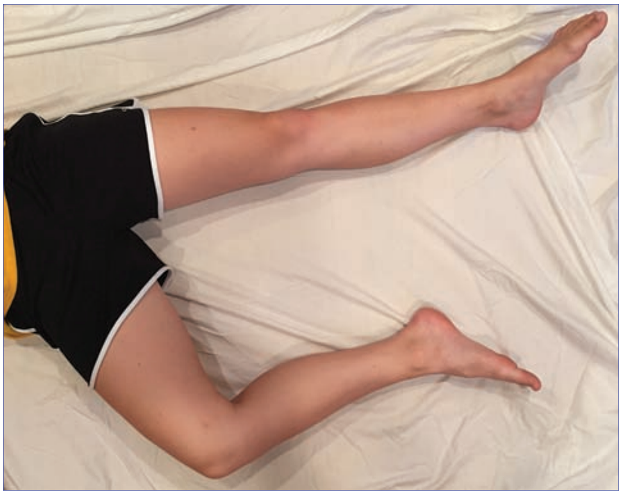


FIGURE 54.7 Anterior hip dislocation. External rotation, abduction, and extension of the hip.

TREATMENT

Hip dislocations can occur anteriorly or posteriorly with the majority occurring posteriorly. Once the type of dislocation is confirmed, a closed reduction may be performed.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Large associated femoral neck, shaft, or pelvic fracture(s), ipsilateral knee injury
- Recent THA, within 3 to 4 months

SPECIAL CONSIDERATIONS

The prosthetic hip can be reduced using any of the following described methods, but warrants special attention. In all hip dislocations, forceful, abrupt reductions should be frowned on and especially when prosthetic hips are involved. The hip prosthesis may dislodge the acetabular cup, fracture underlying osteoporotic bone, or even loosen and cause subluxation of the prosthesis.

- Neurovascular compromise is cause for a prompt reduction.
- The clinician should be comfortable with multiple reduction techniques as no specific technique carries a 100% success rate.

PROCEDURE PREPARATION

- Administer intravenous/intramuscular analgesics early in the course prior to radiography.
- A standard pelvis x-ray is generally sufficient for diagnosis, but additional views are often warranted based on mechanism of injury or suspicion for concurrent injuries (**FIGURE 54.8**).
    - When an anterior dislocation is present, the femoral head is closer to the generator and further from the x-ray film in an anterior to posterior film, which will lead to a magnification of the femoral head (appears bigger).
    - A posterior dislocation, on the other hand, will lead to a femoral head that is closer to the film and further from the generator, leading to the femoral head appearing smaller (**see FIGURE 54.8C**).

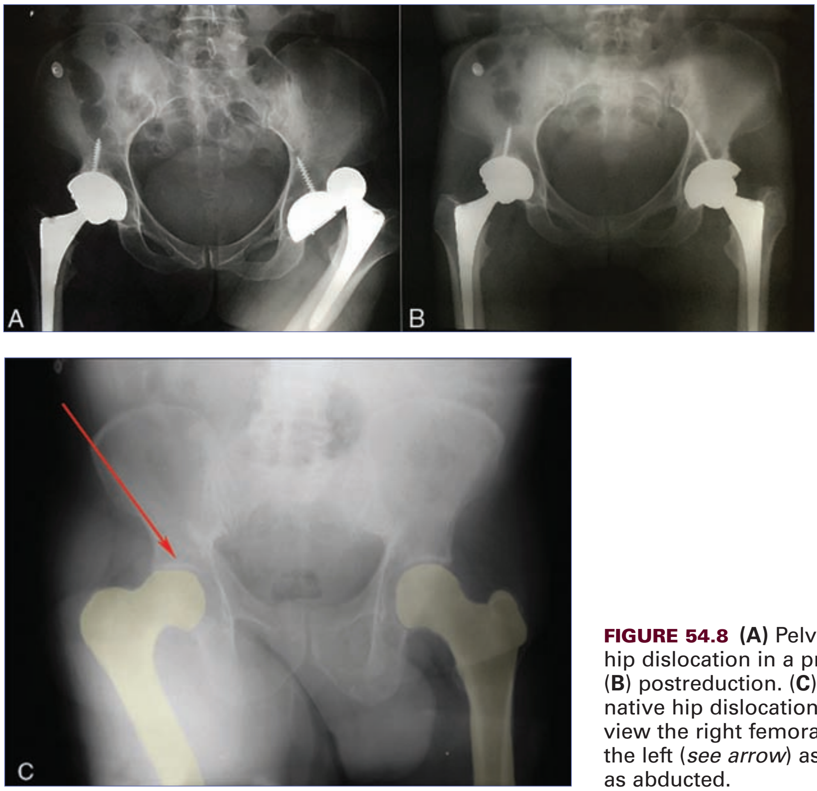


FIGURE 54.8 (**A**) Pelvis x-ray demonstrating a posterior hip dislocation in a prosthetic hip prereduction and (**B**) postreduction. (**C**) Pelvis x-ray showing a subtle right native hip dislocation. Note on this anterior–posterior view the right femoral head is smaller in comparison to the left (*see arrow*) as it is closer to the x-ray plate as well as abducted.

- A lateral view helps delineate anterior versus posterior displacement of the femoral head and allows more subtle fracture detection.
- CT scan is required for further fracture detection, especially regarding the acetabulum.
  - CT is less important for THA dislocation.
  - Specialty CT is required to minimize image degradation from the implant.
- Prepare for procedural sedation.
  - Proper sedation and muscle relaxation cannot be overemphasized in reducing this large, robust, ligamentous, and muscular joint.
    - Cardiac monitor
    - Pulse oximeter
    - End-tidal CO_2 monitor
    - Assistant
    - Analgesia
    - Potent and short-acting sedative
      - Propofol
      - Ketamine
      - Etomidate
    - Carlin et al. (2017) reported the first case of ultrasound-guided femoral nerve block to facilitate a closed reduction of a dislocated hip prosthesis in 2017.
    - West et al. (2017) reported a case in which they utilized a fascia iliaca block (see Chapter 17) for the successful reduction of a traumatic native anterior hip dislocation; systemic sedation was also utilized.
    - However, because the hip joint is innervated by not only the femoral nerve, but the sciatic and obturator as well, a femoral nerve block would appear to be inadequate for complete analgesia of the hip joint.
      - Because of such a plethora of innervation, isolated regional anesthesia of the femoral nerve alone cannot be recommended for adequate anesthesia.

PROCEDURE

Relocation Techniques

- For posterior dislocations, the principles of reduction described in the techniques that are listed generally follow the hip maneuvers of:
  - Flexion
  - Internal rotation
  - Adduction
- Note, for the rare (10%) anterior dislocation, reduction is usually carried out by:
  - In-line traction
  - External rotation
    - With an assistant sometimes pushing on the femoral head or pulling the femur laterally to assist

Techniques for Posterior Dislocations

Techniques were first described as a method for closed reduction of a dislocated hip in 1870. In the last decade, a plethora of reduction techniques have been described. The literature actually describes up to 20 varying methods, each with advantages and disadvantages. We describe the most common methods for posterior hip dislocation.

ALLIS TECHNIQUE

- Allis technique is the second-oldest reduction technique and was described in 1895. It is the most common hip reduction technique utilized (**FIGURE 54.9 AND VIDEO 54.1**).
- Patient is placed in the supine position.

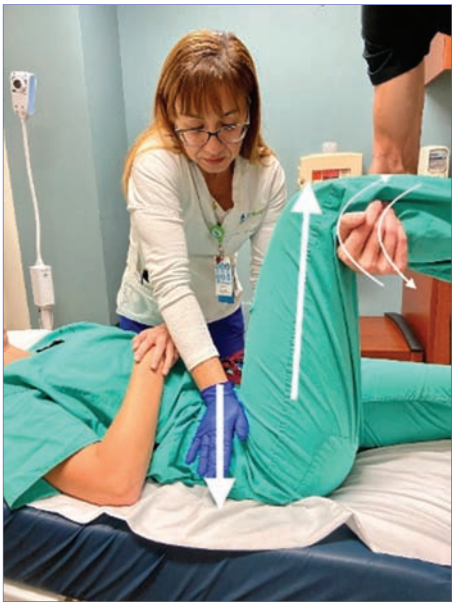


FIGURE 54.9 Allis technique.

- An assistant, while facing the clinician, provides stabilization to the pelvis by pushing posteriorly on the bilateral anterior superior iliac spine (ASIS) with the goal of not allowing the pelvis (acetabulum) to move during femoral head (ball) repositioning.
- The clinician stands on the bed, facing the patient, and places both hands behind the knee/calf of the affected side, lifting the femur anteriorly.
  - The knee and hip will be in 90 degrees of flexion.
- Steady, constant traction is applied anteriorly with simultaneous, gentle internal and external rotation of the femur.
  - Lateral traction on the proximal femur by an assistant may help.
- After reduction is successful, hip is brought to the extended position while traction is maintained.
- Allis technique has a reported 60% success rate (Walden & Hamer, 1999).

WHISTLER TECHNIQUE

- Patient is placed in the supine position (**FIGURE 54.10** and **VIDEO 54.2**).
- An assistant, while facing the clinician, provides stabilization to the pelvis by pushing posteriorly on the bilateral ASIS with the goal of not allowing the pelvis to move during femoral head repositioning.

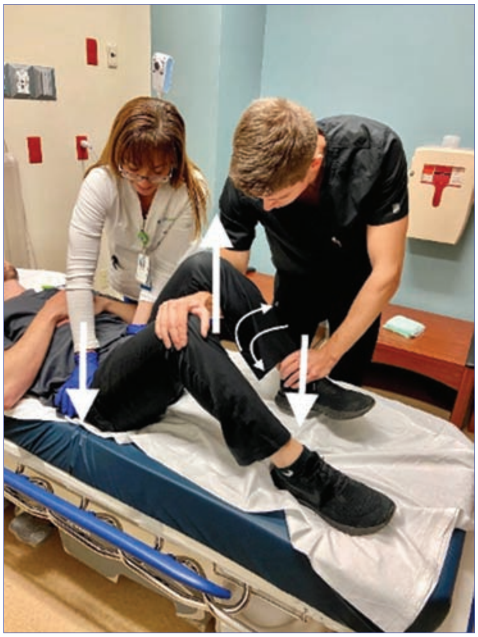
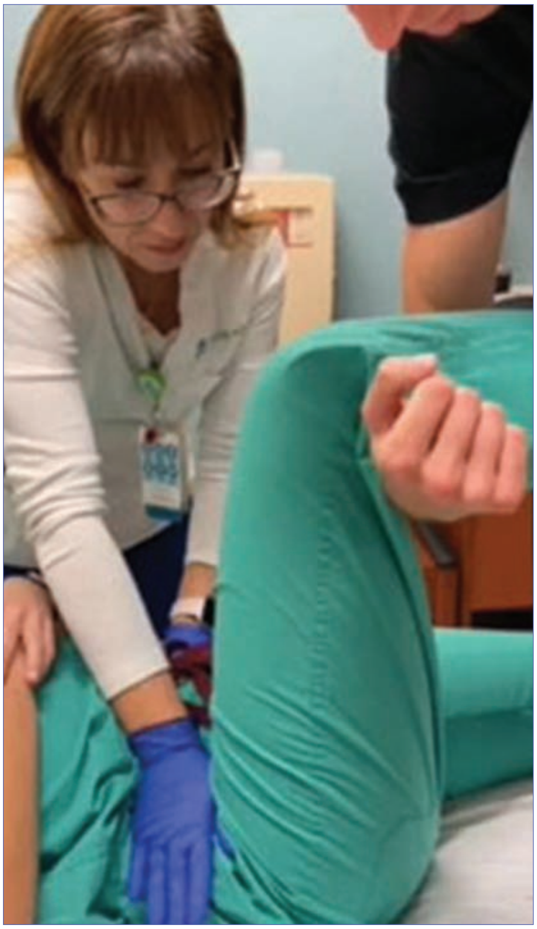
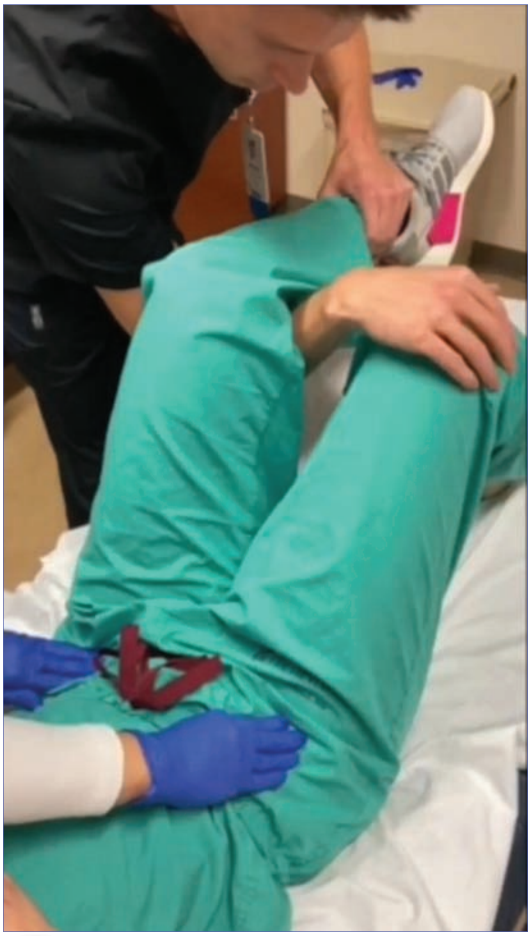


FIGURE 54.10 Whistler technique.



VIDEO 54.1 Allis technique.



VIDEO 54.2 Whistler technique.

- The clinician stands on the affected side, facing the long axis of the stretcher, and places their forearm under the 120-degree flexed, ipsilateral knee while the same hand grasps the 90-degree flexed contralateral knee.
- Using the other hand, the clinician grasps the affected ankle and, firmly pushing toward the bed, stabilizes the ipsilateral leg.
- The clinician, using constant and firm force, raises their arm, which subsequently applies an anterior force to the affected knee, raising the femur anteriorly.
  - The importance of grasping and affixing the affected ankle cannot be overemphasized.
- Slight internal and external rotation of the affected hip, using the forearm as a fulcrum under the affected knee, may facilitate increased success.
- Whistler technique has a 64% successful reduction rate (Walden & Hamer, 1999).

CAPTAIN MORGAN TECHNIQUE

- The Captain Morgan technique was first described in 2011.
- Patient is placed in the supine position (**FIGURE 54.11** and **VIDEO 54.3**).

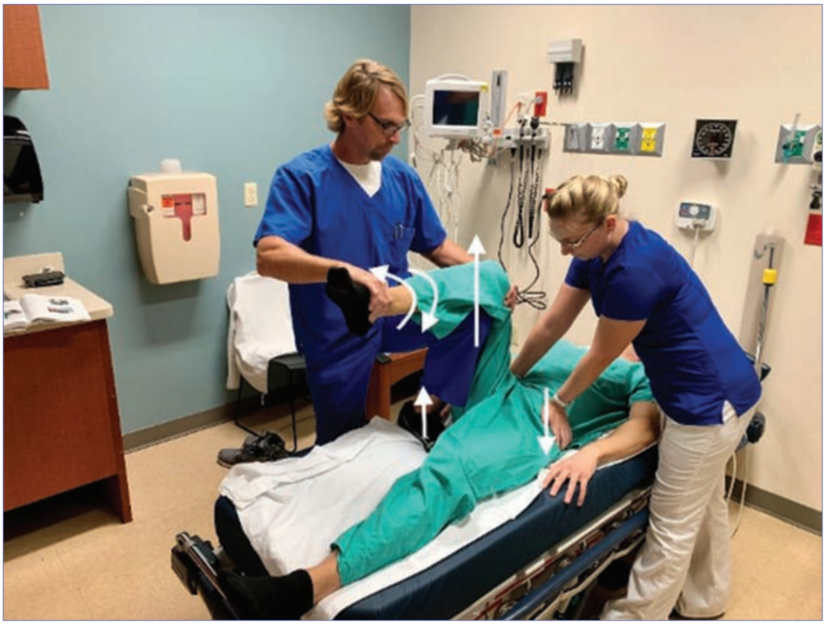
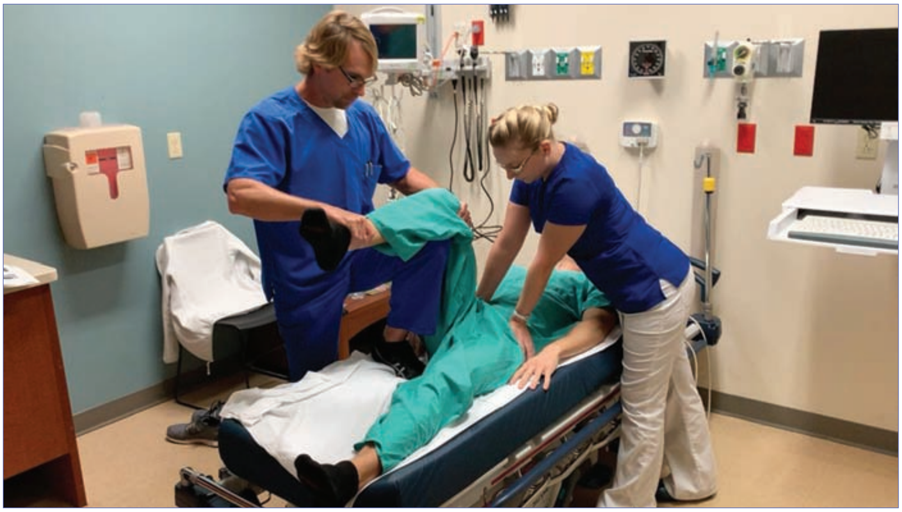


FIGURE 54.11 Captain Morgan technique.



VIDEO 54.3 Captain Morgan technique.

- An assistant, while facing the clinician, provides stabilization to the pelvis by pushing posteriorly on the bilateral ASIS with the goal of not allowing the pelvis to move during femoral head positioning.
- The clinician is perpendicular to the patient on the affected side, and places their flexed knee on the stretcher under the patient's ipsilateral knee and places their foot close to the hip (analogous to the illustration of the infamous rum icon). The clinician will then place one hand under the patient's ipsilateral knee and the other hand over the patient's ipsilateral ankle.
- Flex the patient's affected knee and hip to 90 degrees and, on the unaffected side, maintain hip and knee extension.
- Apply upward, axial force in the direction of the femur via the clinician's knee by flexion of the clinician's calf muscle/plantar flexion. Internally and externally rotate the ipsilateral hip with the patient's ankle as needed.
    - The patient's knee must remain in 90-degree flexion. Applying a slight downward pressure on the patient's ankle may be needed.

BIGELOW MANEUVER

- In 1870, the Bigelow maneuver was the first described closed reduction of a dislocated hip.
- The patient is placed in the supine position (**FIGURE 54.12** and **VIDEO 54.4**).
- The clinician grasps the ankle of the affected leg with one hand and places their opposite forearm under the patient's knee.
- The hip is flexed to 90 degrees, ensuring the affected leg is kept in an adducted and internally rotated position.
- While an assistant stabilizes the pelvis with posterior pressure, the clinician applies traction in line with the femur while abducting, externally rotating, and extending the ipsilateral hip.
- The Bigelow method is used less than other techniques secondary to a paucity of case reports of increased femoral neck fractures in those patients with traumatic hip dislocation.

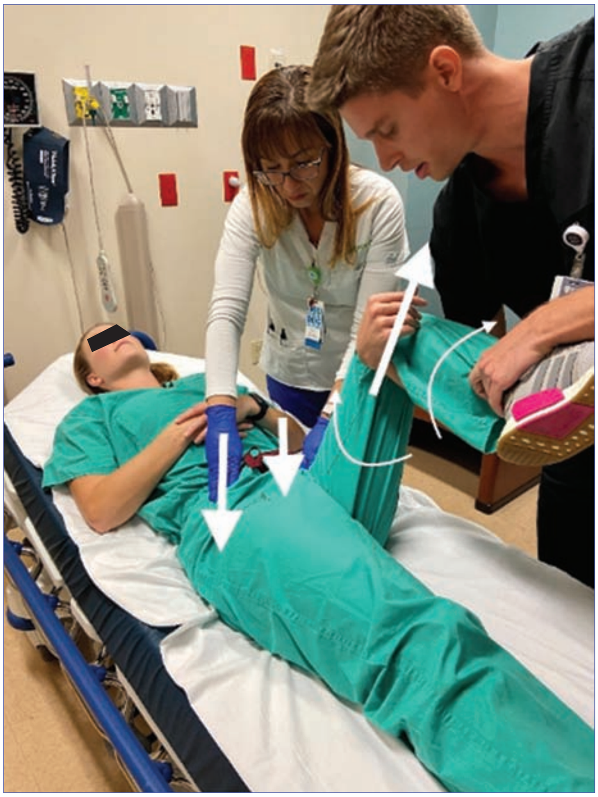
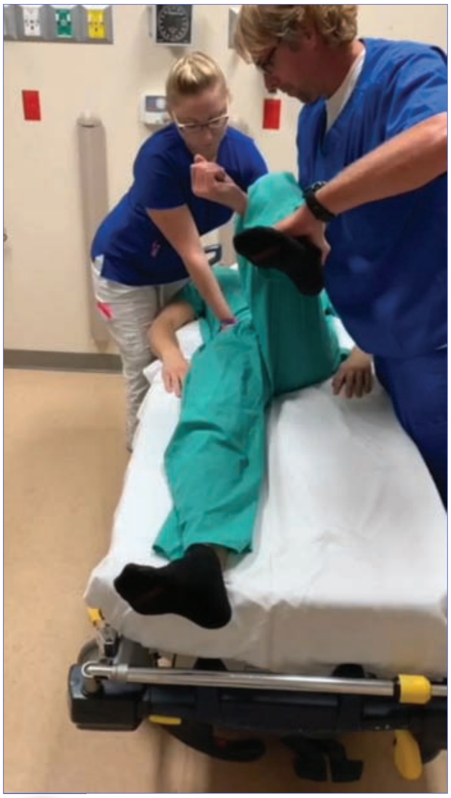


FIGURE 54.12 Bigelow maneuver.



VIDEO 54.4 Bigelow maneuver.

HOWARD MANEUVER

- The patient is placed in the supine position (**FIGURE 54.13** and **VIDEO 54.5**).
- The clinician and an assistant stand on the side of the affected hip.
- The affected hip and knee are flexed to a 90-degree angle.
- An assistant applies lateral traction on the thigh of the affected side while helping to stabilize the pelvis.
- It may help to have another assistant apply downward force on the patient's bilateral ASIS for stabilization of the acetabulum.
- The clinician holds the affected lower leg by grasping the popliteal fossa and ankle, and then applies traction in line of the femur while inducing internal and external rotation until reduction occurs.

PIGGYBACK/ROCKET LAUNCHER TECHNIQUE

- The patient is placed in the supine position with the buttocks at the edge of the bed (**FIGURE 54.14** and **VIDEO 54.6**).
- The affected hip and knee are flexed to 90 degrees. The clinician sits at the far end of the bed and places the affected knee over their other shoulder, using the shoulder as a fulcrum.
- An assistant applies downward force on the patient's bilateral ASIS for stabilization of the acetabulum.
- The clinician applies a downward force on the patient's distal tibia, causing the patient's femur to propel away from the body.
- The clinician can increase the force by using their legs to squat and further "launch" the patient's leg anteriorly; this is held until reduction is complete.
- This technique showed an 83% success rate in one study (Dan, Phillips, Simonian, & Flannagan, 2015).

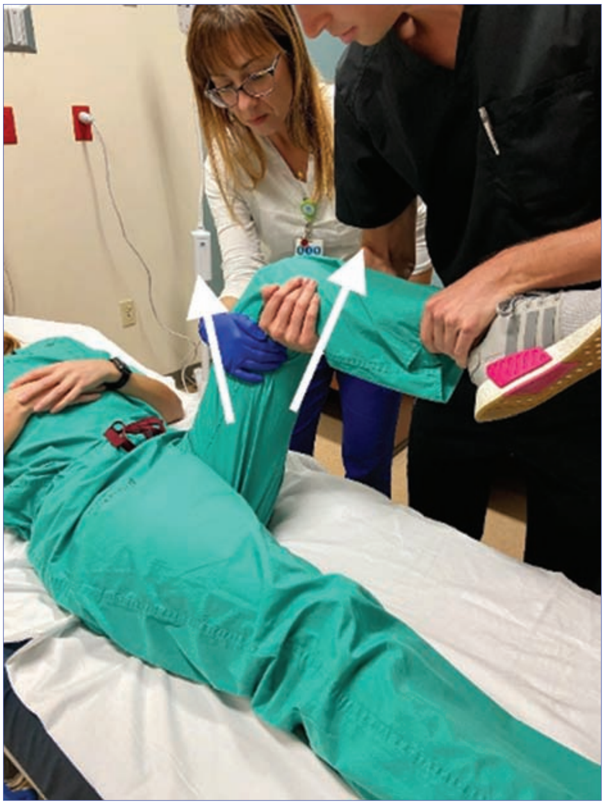
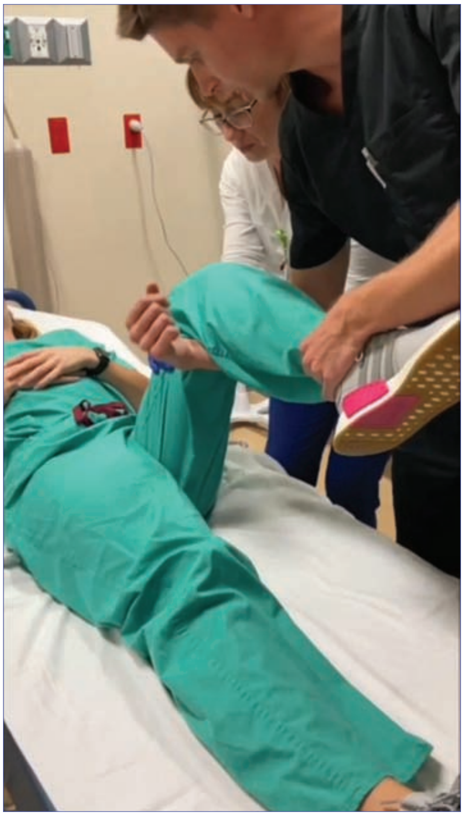


FIGURE 54.13 Howard maneuver. Note that an additional assistant may be necessary to stabilize the pelvis.



VIDEO 54.5 Howard maneuver.

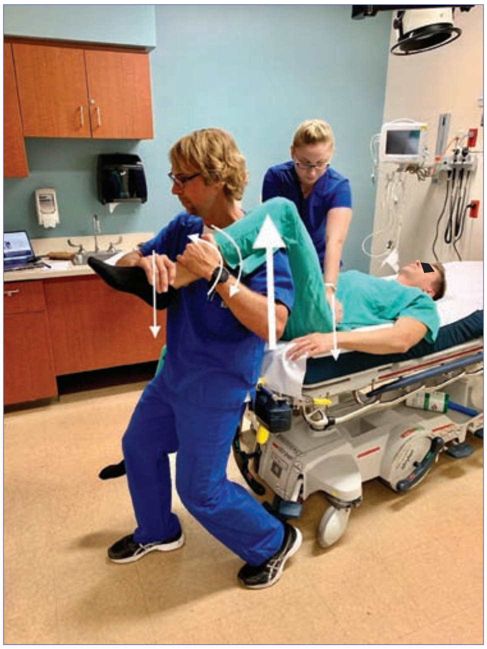
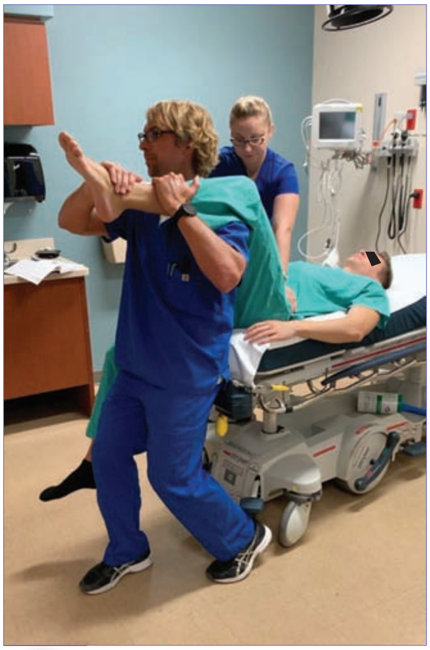


FIGURE 54.14 Piggyback/rocket launcher technique.



VIDEO 54.6 Piggyback/rocket launcher technique.

Considerations for Anterior Dislocations

The techniques listed are commonly used for posterior hip dislocations (90%). When faced with reducing an anterior dislocation (10%), slight modifications to these procedures are necessary. Two types of anterior dislocation are described: obturator dislocation and pubic dislocation. Each of these situations requires slight variations but still require hip extension, in-line traction, and external rotation for reduction. When a pubic dislocation is present, flexion of the hip is not usually possible due to position of the femoral head resting on the anterior surface of the pelvis. Hyperextension and in-line traction are required for reduction to occur. An obturator dislocation is most commonly reduced with hip flexion, adduction, and external rotation.

POSTPROCEDURE CONSIDERATIONS

- Neurovascular reassessment is paramount and should always be verified following relocation.
  - Test for sciatic nerve integrity. Specifically, the sensory and motor portions of the peroneal nerve
    - Sensation to the anterior/dorsal foot and lateral legs and to the top of the feet
    - Dorsiflexion
- In order to prevent immediate and remote recurrence, immobilize the leg with an abduction pillow or a knee immobilizer (**FIGURE 54.15**).
- Postreduction x-rays should be done to verify reduction.
- Consultation with the orthopedic surgeon who performed the THA is necessary to ensure a long-term treatment plan following reduction. For native hip dislocations, orthopedic surgery should be consulted during the ED visit.

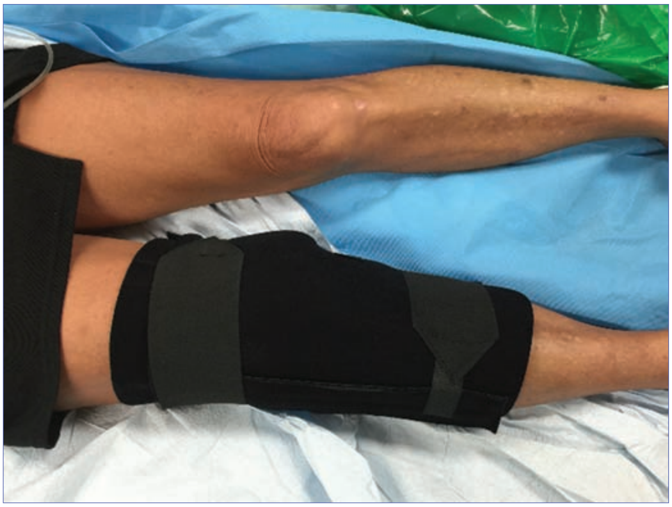


FIGURE 54.15 Knee immobilizer placed immediately after successful reduction to prevent redislocation.

EDUCATIONAL POINTS

- Consultation with the orthopedic surgeon who performed the hip prosthesis should be considered prior to attempting reduction in patients who are 3 to 4 months postoperative THA.
- Anterior versus posterior surgical approach gives clues as to the direction of THA dislocation.
- Evaluate the surgical site, as infection may also contribute to THA dislocation, especially in the early postoperative period.
- Never apply sudden, forceful, jerking movements on reduction of hip dislocations as this increases the chance of iatrogenic fracture.
- Rehabilitation of patients with sciatic nerve injury must begin as early as possible and should focus on the prevention of an equinus foot deformity, which is a chronic foot drop from peroneal nerve injury.
- In all instances, neurovascular examination is imperative before and after any reduction is attempted.
- The secondary trauma survey should include an assessment of the hips and other large joints.
- Associated fractures are common (88%) in traumatic hip dislocations. Minor fractures are not a contraindication for emergent reduction.

COMPLICATIONS

- AVN of the hip in 15% of cases
- Increased with:
  - Delayed reduction
  - Multiple reduction attempts
  - Open reduction
- Sciatic nerve injury
  - 10% occurrence in PHD
- Osteoarthritis
- Heterotopic calcification
- Recurrent dislocations
- Complications of immobilization
  - Deep vein thrombosis
  - Pulmonary embolism
  - Decubitus ulcer
  - Pneumonia
  - Femoral nerve injury

PEARLS

- PID can be used as an acronym to describe hip positioning in PHDs; "**P**HD **I**nternal rotation a**D**duction."
- The clinician should be comfortable with multiple techniques for hip dislocation as no single technique is 100% successful.
- Adequate sedation and muscle relaxation are integral to successful hip reduction. Attempts without it, in most cases, are futile.
- Documentation of the patient's neurovascular status pre/postreduction is paramount.
- Admit traumatic hip dislocations and discharge most prosthetic dislocations.
- Traumatic native hip dislocations should be evaluated as a major trauma due to the high likelihood of multiple injuries and fractures, including but not limited to head, neck, and intra-abdominal traumatic pathologies.
- In a multi-injured patient, always put the joints through full range of motion on the secondary survey to ascertain a subclinical luxation/subluxation.
- After successful reduction of a prosthetic hip, the patient can be discharged home if trivial trauma is the etiology. This is not the case for traumatic native hip dislocations.
- Resist sudden, jerky, and abrupt forceful movement at all times.
- Always use an assistant.
- Although described techniques are viable for the reduction of dislocated hips, we suggest using newer modified techniques for posterior hip dislocations in order to decrease the strain on the reducing clinician's back and limit standing on a stretcher to decrease potential clinician harm.

RESOURCES

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CHAPTER 55

Procedures for Patella Dislocation

Norah Wright, Derek Isenberg, and Keith Lafferty

BACKGROUND

The patella is a triangular sesamoid bone that is held in the patellofemoral groove superiorly by the quadriceps tendon and inferiorly by the patellar tendon. The vastus medialis and vastus lateralis muscles also help to anchor the patella in place. The medial patellofemoral ligament (MPFL) horizontally attaches the patella to the adductor tubercle, where the adductor magnus tendon attaches as well. This ligament is the most commonly injured structure during a patellar dislocation and, as such, explains the predominant lateral dislocation (**FIGURE 55.1**). The medial and lateral collateral ligaments assist in stabilization on either side. A lateral (most common) patellar dislocation occurs when the MPFL is stressed and torn with the sequela of the patella slipping out of its normal position, usually occurring as the result of a lateral twisting motion with the knee flexed slightly as both of these positions place the greatest stress on the MPFL. Often, this is a sports-related injury.

Patellar dislocation occurs in about six per 100,000 people per year and represents 2% of all knee injuries. It is most common in teenagers, with slightly higher rates in women. Up to 25% have a familial history of patellar dislocation secondary to slight anatomical anomalies. The mechanism of injury usually involves twisting the leg against an externally rotated and slightly flexed knee, again resulting in stress and an ensuing tear of the MPFL. Because of such, the patella is typically displaced laterally over the lateral condyle of the femur (**FIGURE 55.2**). Medial, inferior, and superior dislocations rarely occur, but when they do, they are typically more severe and often require surgical repair as these violate the extensor mechanism of the knee.

The typical case of patellar dislocation involves an adolescent playing a sport that requires a sudden slight knee extension, external rotation, and valgus maneuver (all three maneuvers place stress on the MPFL), which commonly occurs in sports such as ice hockey or gymnastics. Although less common, dislocation can result from a direct blow to the anterior–medial patella while the knee is extended. Up to 50% of patients will have recurrent dislocations.

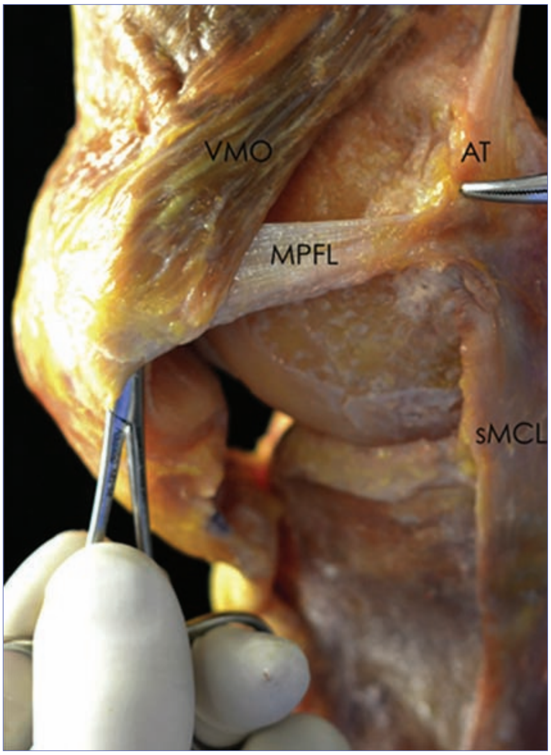


FIGURE 55.1 Cadaveric dissection showing the taut medial patellofemoral ligament.

AT, adductor tubercle; MPFL, medial patellofemoral ligament; sMCL, superficial medial condyle; VMO, vastus medialis oblique.

Source: Dean, C., Chahla, J., Serra Cruz, R., Cram, T., & LaPrade, R. (2016). Patellofemoral joint reconstruction for patellar instability: Medial patellofemoral ligament reconstruction, trochleoplasty, and tibial tubercle osteotomy. *Arthroscopy Techniques*, *5*(1), e169–E175. https://doi.org/10.1016/j.eats.2015.10.016

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

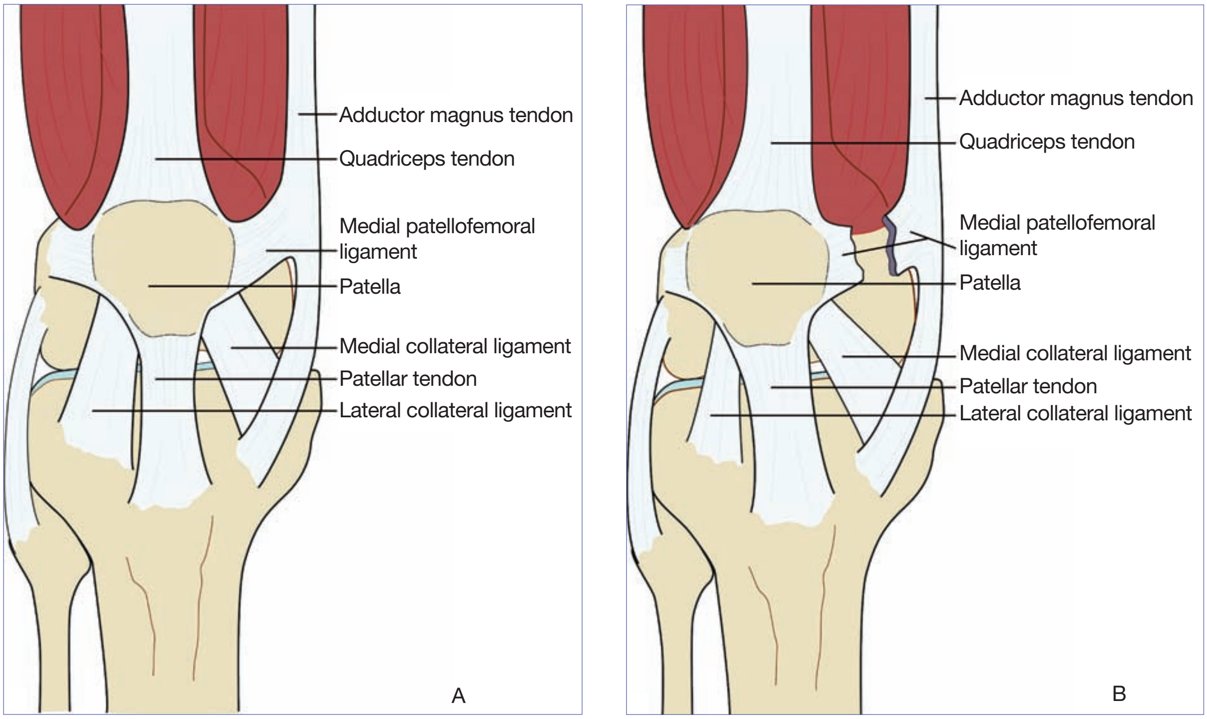

Adductor magnus tendon
Quadriceps tendon
Medial patellofemoral ligament
Patella
Medial collateral ligament
Patellar tendon
Lateral collateral ligament
A
Adductor magnus tendon
Quadriceps tendon
Medial patellofemoral ligament
Patella
Medial collateral ligament
Patellar tendon
Lateral collateral ligament
B

FIGURE 55.2 Knee anatomy. (A) Normal compared to (B) a medial patellofemoral ligament tear. Note that up to 80% of the medial stability of the patella comes from the MPFL and occurs mostly from 0° to 30° flexion.

MPFL, medial patelloform ligament.

Genetic anatomical abnormalities usually play a role in patellar dislocations and subsequent instability postreduction:

- Trochlear dysplasia—90%
- Increased lateral patellar tilt greater than 20° occurs in 83% of cases and patella alta occurs in 24% of dislocations
- Increase in the distance between the tibial tuberosity and the center of the trochlear groove is 56%
- Longer (30%) and/or thinner MPFL (50%)

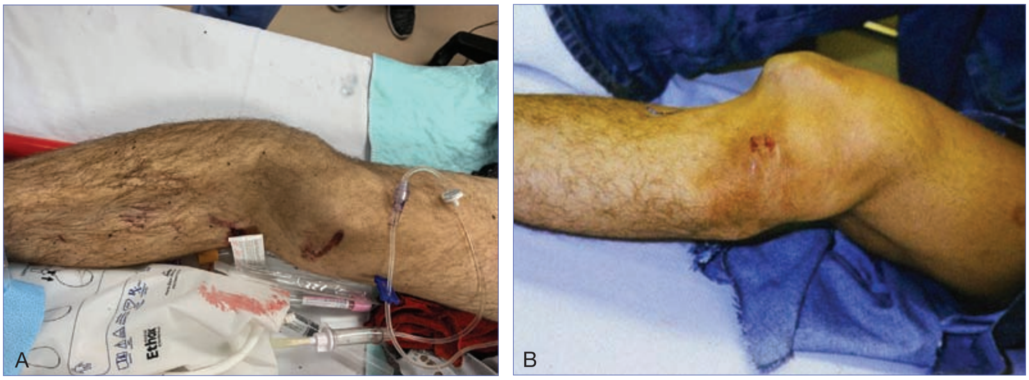
It is important not to confuse a patellar dislocation with a tibiofemoral (knee) dislocation. This is most common in obese females; up to 24% display a family history of this injury. This represents a true knee dislocation and is an orthopedic emergency as up to 30% to 50% of cases have an associated popliteal arterial injury (**FIGURE 55.3**).

PATIENT PRESENTATION

Typically, a patient presenting with a patellar dislocation will hold the extremity in partial flexion and has a laterally displaced patella on exam. A knee effusion may also be present. The patient will be unable to fully extend the knee or ambulate on that extremity. With the knee in mild flexion, there may be some visible skin tenting over the patella (**FIGURE 55.4**).

Many cases of patellar dislocation will spontaneously reduce prior to arrival to the hospital, and therefore a high index of suspicion is required for these injuries. Clues may include:

- Knee effusion
- Tenderness over the MPFL
- Bedside ultrasound over the medial knee showing disruption of the MPFL (see following text)
- Positive patellar apprehension test, which carries a positive/negative likelihood ratio of 1.3/1.0, respectively.
  - With the knee slightly flexed to 30 degrees (relaxes the quadriceps), the medial edge of the patella is gently moved laterally; if the patient either grabs the clinicians' hands or extends the knee in order to stop the maximal lateral displacement, it is considered a positive test.
- Patients say things, such as, "My knee gave out and then went back."



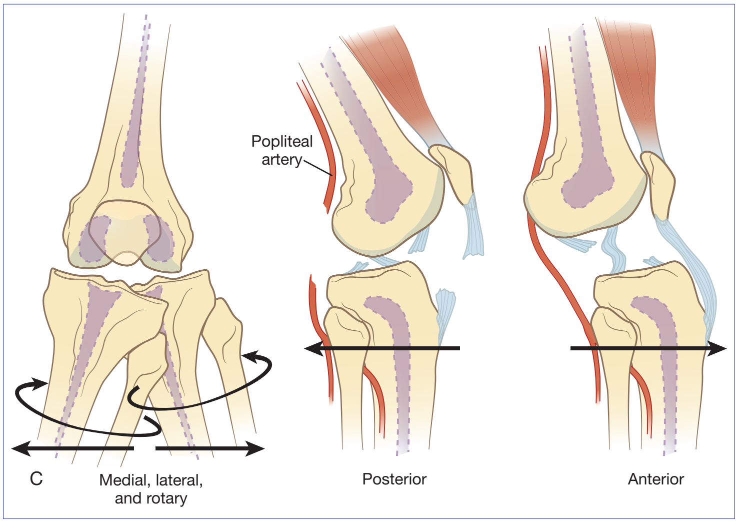


FIGURE 55.3 True knee dislocation. In a tibiofemoral dislocation, there is complete instability of the tibiofemoral (knee) joint. Shown in (A) and (B) are a lateral and posterior dislocation, respectively. A popliteal artery injury (C) must be assumed and evaluated as up to 50% of knee dislocations carry such a potential injury. Distal palpable pulses do not rule out this pathology and vascular imaging is in order. Unlike a patellar dislocation, this is a true vascular emergency.

Source: (B) Kelleher, H. B., & Mandavia, D. (2019). Knee dislocation. In B. E. Brenner (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/823589-overview.

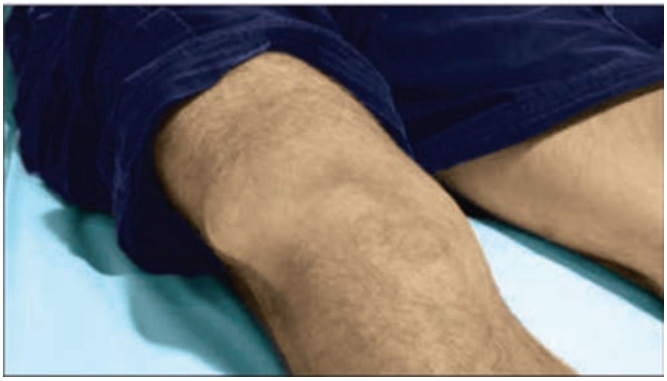


FIGURE 55.4 Patellar dislocation. Note slight flexion of knee and lateral displacement of the patella.

TREATMENT

Reduction of a lateral patellar dislocation is a generally simple and safe procedure. Closed reduction may even occur spontaneously. X-rays are not necessary for identification of a patellar dislocation, as this is a clinical diagnosis, but may be obtained to detect other associated injuries such as osteochondral fractures (**FIGURE 55.5**), which are reported to occur in as many as 50% of patellar dislocations, although most are later identified during arthroscopy or MRI.

Immediate reduction should be performed if there is any associated vascular compromise of the distal extremity. This is extremely uncommon in the setting of an isolated patellar dislocation and should prompt the clinician to seek a concurrent or other diagnosis (tibiofemoral dislocation). MRI is not necessary in the emergent setting, but can further delineate ligamentous injuries at follow-up.

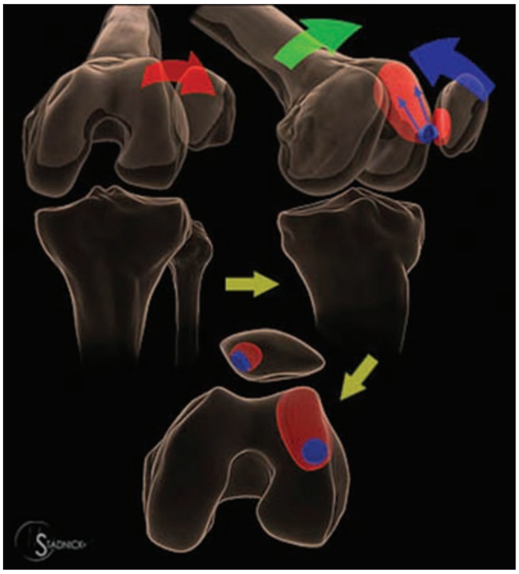


FIGURE 55.5 Mechanism and areas of osteochondral fractures in patella dislocation and reduction. Graphical depictions of the mechanism of patellar dislocation: With the knee in flexion, the patella dislocated laterally. Because the knee is flexed in dislocation, the patella impacts the weight-bearing surface of the lateral femoral condyle. An osteochondral fracture may occur at the lateral femoral condyle upon dislocation, or, more commonly, during relocation at the medial patella. Medial patellar osteochondral fractures may likewise occur during either the dislocation or reduction phases of injury for the same mechanism. Note that up to 50% of such injuries are reported and are represented in the combined red/blue area in the diagram.

Source: Ballehr, L. (2013). *Transient lateral patellar dislocation*. Retrieved from https://radsource.us/transient-lateral-patellardislocation

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

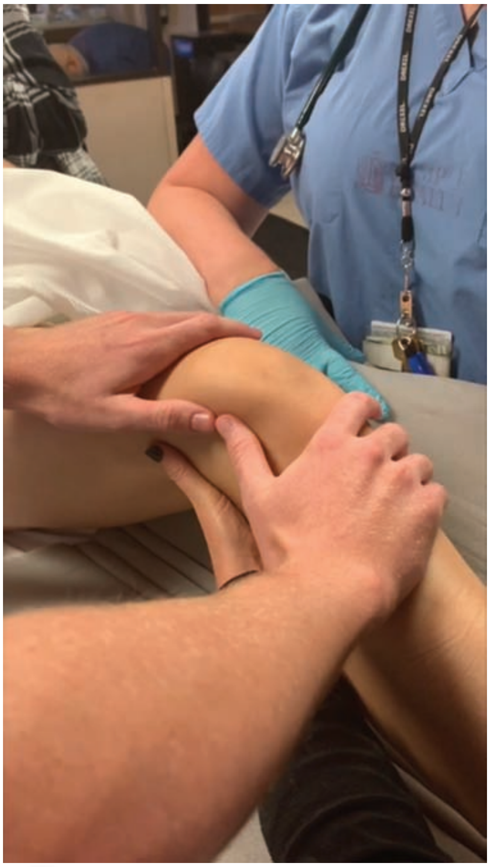
- Associated distal femur fracture
- Associated proximal tibial fracture

PROCEDURE PREPARATION

Prior to beginning the procedure, informed consent should be obtained. Procedural sedation is typically not required but such medications can be used in cases with significant pain or anxiety. A knee immobilizer and crutches should be obtained for aftercare.

PROCEDURE

- The procedure is done at bedside (often while the patient is still on the emergency medical services' stretcher) with the patient laying supine and the affected extremity in slight flexion.
  - Preprocedural x-rays are not required although postprocedural x-rays are as up to 50% of cases have associated osteochondral fractures, though many are discovered later via MRI or arthroscopy.
- For a lateral dislocation, the clinician should stand on the lateral side of the leg and may need to slightly flex the injured leg in order to decrease tension on the quadriceps.
- While extending the knee, the clinician will simultaneously apply gentle anterior–medial pressure to the lateral edge of the patella in order to lift it over the lateral femoral condyle (**VIDEO 55.1**).
- This same technique can be used for a rarely encountered medial dislocation but would require the clinician to stand medial to the dislocation and apply anterolateral force to the medial edge of the patella.
- Successful reduction results in restoration of the normal knee anatomy (**FIGURE 55.6**).



VIDEO 55.1 Patellar dislocation, closed reduction. For this typical lateral dislocation, the clinician is positioned on the lateral side of the extremity, placing both thumbs on the lateral patella edge. While simultaneously applying gentle and constant pressure in an anterior–medial manner, extension of the knee should occur (the latter is not displayed in this video). Note the obvious success and normal alignment resulting from the lateral edge of the patella lifting over the lateral femoral condyle.

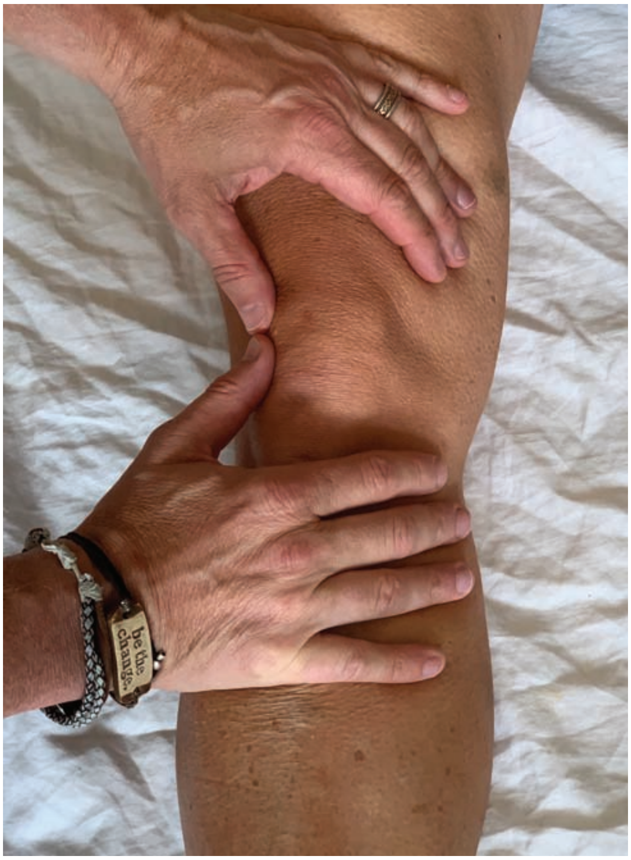


FIGURE 55.6 Patellar dislocation, successful reduction with return of normal alignment.

ULTRASOUND GUIDANCE

Although not commonly used in practice in regard to patellar dislocations, ultrasonography can be used in the assessment of a patellar dislocation. Knee effusions can easily be identified on ultrasound and, in cases of prehospital self-reductions, may clue the clinician into the diagnosis. The MPFL appears as a bilaminar hypoechoic structure at the level of the patella, appearing thicker at the point of patellar attachment. Ultrasound may show a tear at either the patellar (most common point of tear) or the adductor tubercle (femoral attachment) as well as possibly identifying an avulsion fracture (**FIGURE 55.7**). The MPFL is most easily injured at the femoral attachment.

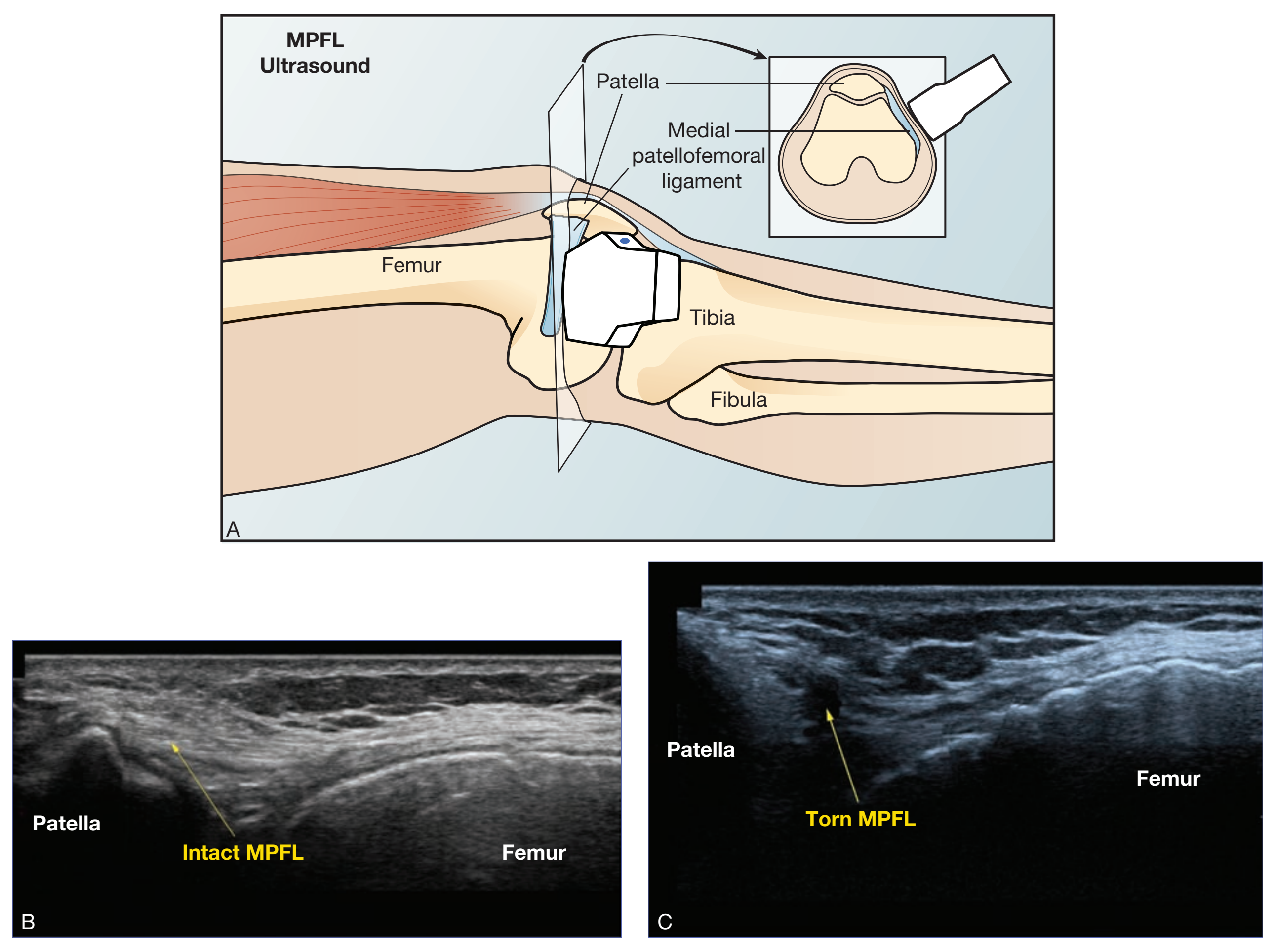


FIGURE 55.7 Medial patellofemoral ligament ultrasound. (A) Place the patient in a supine position with the knee in 30° flexion and hip slightly externally rotated. Using a transverse orientation, place the probe on a plane with the mid patella over the medial knee joint. Secondary to this ligament being extraarticular, it lends itself to sonography and originates just superior to the medial collateral ligament. MPFL is triangular in shape and has a wider girth on the patella attachment point as opposed to the thinner band portion that attaches to the adductor tubercle of the distal medial femur. (B) Intact MPFL. Note the organized fibrillar connective tissue. (C) Torn MPFL. Note the disruption (hypoechoic area) in the fibrillar ligament (now disorganized) closer to the patella attachment point (usually torn near its femoral attachment point). In both ultrasound images, observe the hyperechogenic bone structures with posterior shadowing.

MPFL, medial patellofemoral ligament.

Source: Figures (B) and (C) courtesy of Thomas Constantino, MD.

POSTPROCEDURE CONSIDERATIONS

After reduction, the extremity is placed in a knee immobilizer for 3 to 6 weeks in order for the medial patellar retinaculum to heal. After a period of immobilization, physical therapy may be required to improve the strength and integrity of the surrounding ligaments and tendons. Athletic tape and braces may be used to prevent reinjury or recurrent dislocation. Nonsteroidal anti-inflammatory drugs are often used to minimize symptoms and inflammation.

Though surgery has not shown a consistent benefit after a first-time dislocation, consensus is that it is indicated in patients who are found to have an:

- Intraarticular fracture
- Concurrent osteochondral injury
- Continued instability/recurrent dislocations
  - 50% of patients
- Complete destruction of the MPFL

Surgical techniques include:

- Arthroscopic release of the lateral retinaculum to blunt its pulling force on the patella laterally
- Medial imbrication
  - Tightens the medial retinaculum/MPFL
- MPFL reconstruction
  - Cadaveric
  - Allograft

Though a prospective, randomized, controlled study showed that surgical stabilization significantly reduced the redislocation rate of primary traumatic patellar dislocation in a young-adult population more than in those without surgical treatment, a clear subjective benefit of such initial stabilizing surgery was not seen at the time of long-term follow-up.

EDUCATIONAL POINTS

- Patellar dislocation typically occurs from a sudden change in direction of the knee when the extremity is planted such as occurs in “cutting” in ice hockey.
- Lateral dislocations are the norm.
- Imaging is not required for diagnosis but can help to identify associated injuries such as osteochondral fractures, which occur in up to 50% of the cases.
- Reduction is performed by applying gentle and constant anterior–medial pressure to the lateral patella in order to reduce it over the lateral femoral condyle.
- After reduction, patients should remain in a knee immobilizer for 3 to 6 weeks in order to allow MPFL to heal and to prevent further injury.
- Recurrent dislocations occur in up to 50% of patients.
- Orthopedic follow-up is required for all patients.

COMPLICATIONS

Osteochondral fractures are a very common complication of this procedure. Postreduction radiographs may be obtained in order to investigate for this injury though more will be discovered later via MRI and/or arthroscopy. Related complications of the dislocation itself may include recurrent dislocations, degenerative arthritis, or osteochondral fractures.

PEARLS

- Preprocedural sedation is often not required.
- ***X-rays delay reductions; obtain imaging after closed reduction*** in order to review possible associated fractures, which are usually at the lateral femoral condyle or the medial margin of the patella.
- If the reduction is unsuccessful, the medial facet of the patella may be locked on the lateral femoral condyle, which will require downward pressure on the lateral edge of the patella.
- Many cases self-reduce before presenting to the hospital; maintain a high sense of suspicion.
- Patients presenting with complete ligamentous disruption of the knee with or without a deformity should be suspected of having a spontaneous knee (tibiofemoral) dislocation and should be treated as such.

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CHAPTER 56

Ankle Dislocations

Regina Saylor and Edward Siegel

BACKGROUND

Ankle dislocations are rare injuries that most commonly occur with high-energy impact on the foot, such as with falls, sports injuries, and motor vehicle accidents. ***Due to the inherent strength of the ankle joint, most ankle dislocations are associated with fractures disrupting the ankle mortise.***

Anatomy

The ankle joint is a synovial hinge joint formed by the distal epiphyses of the tibia and fibula (medial and lateral malleoli), which—along with the tibial bony arch—comprise the ankle mortise; the talus articulates in this mortise (**FIGURES 56.1** and **56.2**).

The joint is intrinsically stabilized by its bony anatomy and further supported primarily by the lateral collateral ligament (LCL) and the thick medial collateral ligament (MCL), also known as the *deltoid ligament*. The LCL is

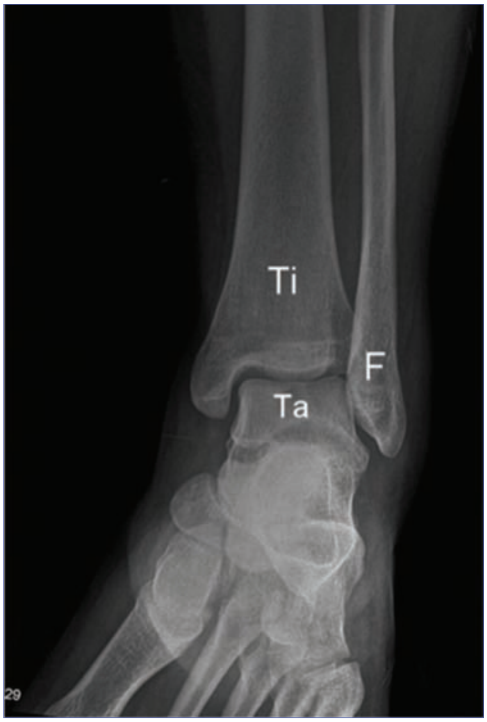


FIGURE 56.1 Anteroposterior x-ray.
F, fibula; Ta, talus; Ti, tibia.

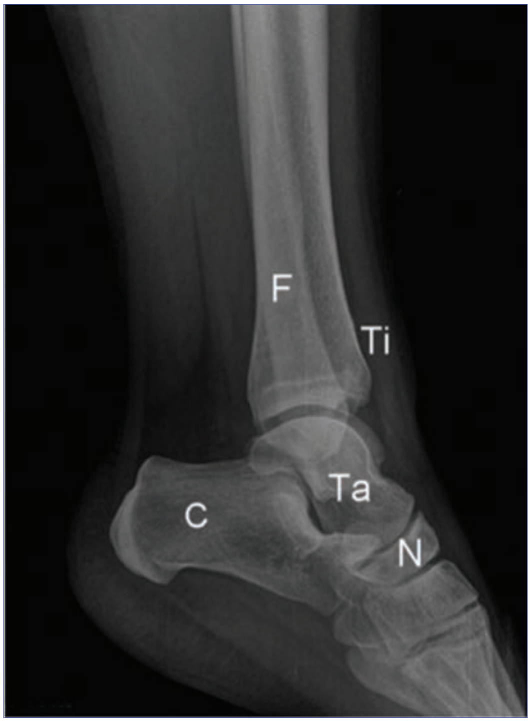


FIGURE 56.2 Lateral x-ray.
C, calcaneus; F, fibula; N, navicular; Ta, talus; Ti, tibia.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

composed of the anterior talofibular (most common ligamentous injury in an ankle sprain), calcaneofibular, and posterior talofibular ligaments (**FIGURE 56.3**). The joint capsule alone stabilizes the joint in the anterior and posterior aspects.

Classification and Mechanism

Ankle—that is, tibiotalar—dislocations are classified by the direction of the talar displacement from the tibia. There are five types of dislocations (summarized in **TABLE 56.1**).

- Anterior
- Posterior
- Medial
- Lateral
- Superior

Of these, posteromedial dislocations are most common. Anatomically, the anterior aspect of the talus is wider than the posterior aspect, allowing for greater range of motion and creating less mortise stability with plantar flexion compared to dorsiflexion. Accordingly, the joint is most commonly dislocated posteriorly with concomitant displacement either laterally or medially.

Due to the bony and ligamentous strength of the joint, pure tibiotalar dislocation is an exceptionally rare injury limited to case reports in the literature; most are associated with concomitant malleolar or talar fractures.

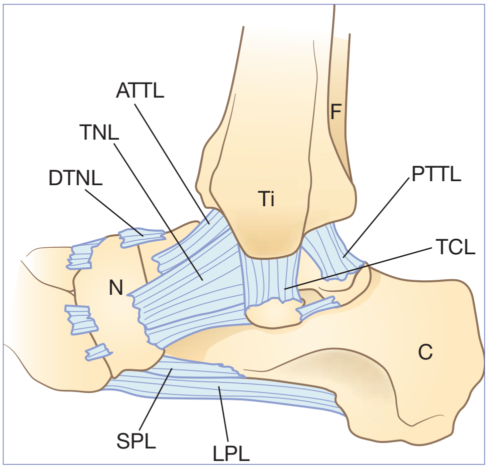


FIGURE 56.3 Anatomy of the tibiotarsal joint, medial view. Among the others, anterior (ATTL) and posterior tibiotalar ligaments (PTTL), dorsal talonavicular ligament (DTNL), tibionavicular ligament (TNL), tibiocalcaneal ligament (TCL), short plantar ligaments (SPL), and long plantar ligaments (LPL) are indicated.

ATTL, anterior tibiotalar ligament; C, calcaneus; DTNL, dorsal talonavicular ligament; F, fibular; LPL, long plantar ligament; N, navicular; PTTL, posterior tibiotalar ligament; SPL, short plantar ligament; TCL, tibiocalcaneal ligament; Ti, tibia; TNL, tibiocalcaneal ligament.

TABLE 56.1 Ankle Dislocation Classifications, Mechanisms, and Associated Injuries

Classification	Mechanism	Associated Injuries
Anterior	■ Forced dorsiflexion ■ Direct posterior force to distal tibia	■ Dorsalis pedis injury
Posterior	■ Axial load on plantar flexed foot	■ Lateral or medial dislocation injuries
Lateral	■ Forced eversion	■ Lateral malleolar fracture ■ Distal fibular fracture ■ Talotibial ligament tear ■ Medial joint capsule rupture
Medial	■ Forced inversion	■ Medial malleolar fracture ■ Anterior talofibular, calcaneofibular ligament tears
Superior	■ Significant axial load	■ Tibiofibular diastasis ■ Calcaneal fracture ■ Spinal compression fracture

PATIENT PRESENTATION

Patients typically present with gross deformity of the ankle, edema, ecchymosis, and pain (**FIGURE 56.4**). ***History often involves high impact*** such as sports injury, motor vehicle accidents, or falls. Diagnosis can be more challenging if the dislocation is subtle or in the context of obesity or significant edema. The patient may complain of pain at the site of injury and numbness or tingling of the foot. A clinician should be aware of presentations with:

- Neurovascular compromise
  - Although popliteal artery damage has been reported at a high rate following knee dislocation, ***arterial damage*** following ankle dislocation is rarely seen and is limited to case reports.
  - In patients without a pulse initially, immediate reduction is in order; if still no pulse, emergent arteriography and vascular consultation are warranted.
- Tenting of the skin
- Open fractures such as these can alter management (**FIGURE 56.5**)

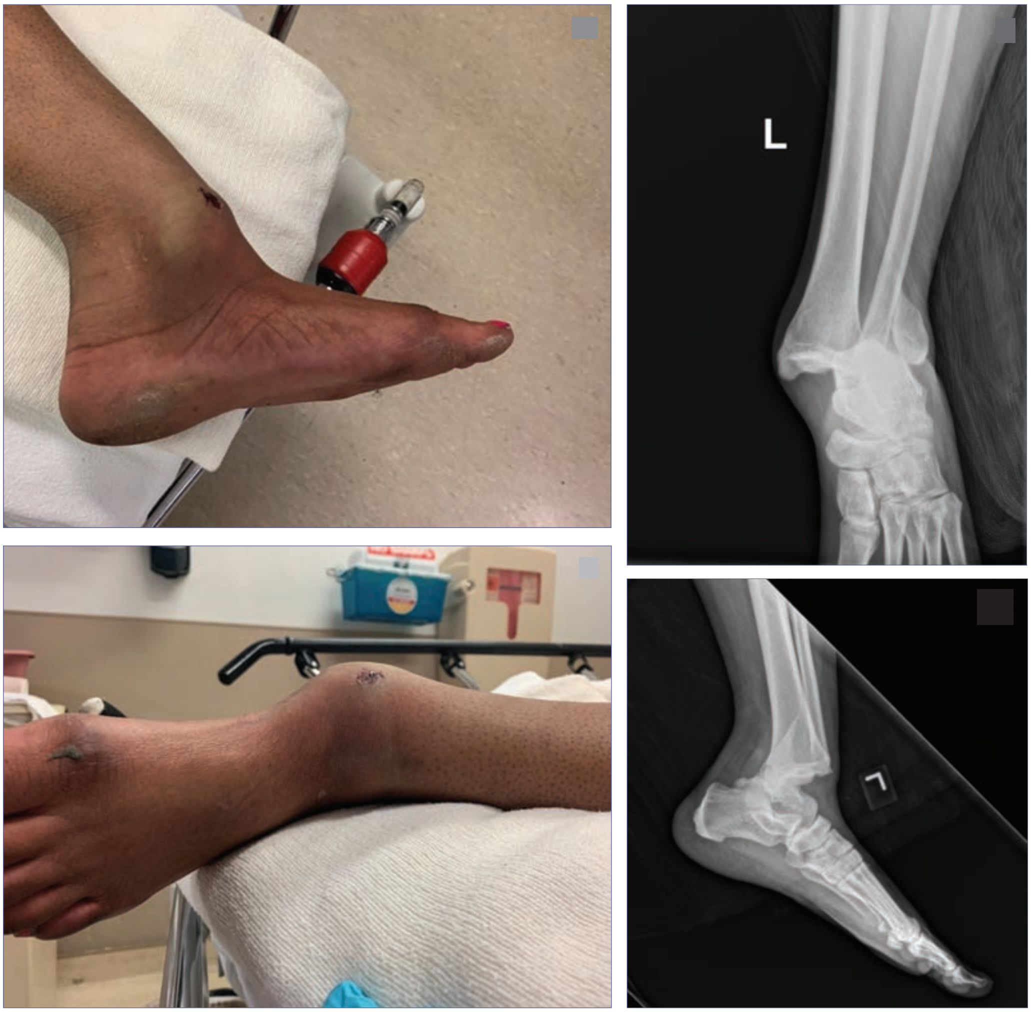


FIGURE 56.4 Tibiotalar dislocation with associated fracture. Because of the intrinsic strength of the ankle joint, almost all ankle dislocations have associated fractures. Note the gross deformity.

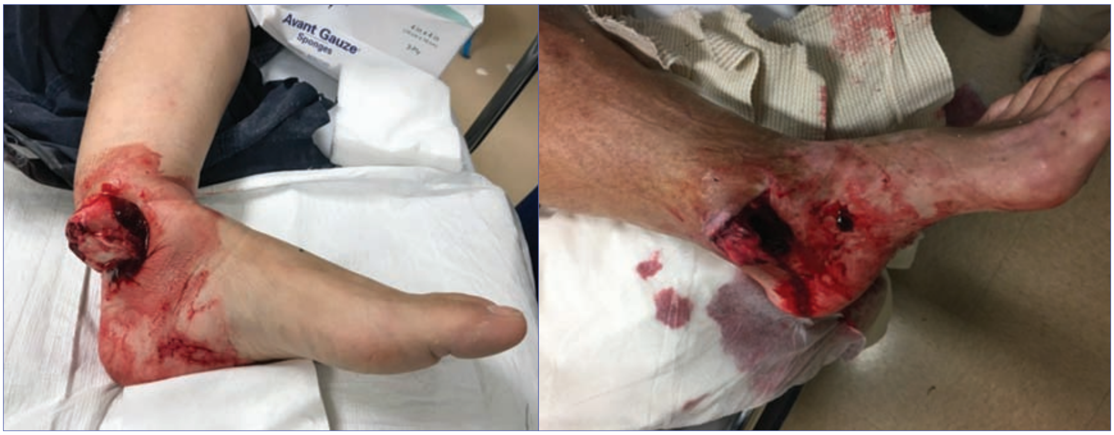


FIGURE 56.5 Open tibiotalar dislocation. Note there was an absent dorsalis pedis pulse and decrease in capillary refill, which necessitated an immediate reduction (before x-rays) and subsequently, a return of pulse and capillary refill.

TREATMENT

- Physical exam and neurovascular assessment
  - Immediately assess neurovascular status and degree of skin compromise.
    - ***Vascular compromise and/or significant skin tenting are indications for prompt reduction without prereduction films.***
  - Identify dislocation classification.
  - ***Assess mechanism and suspicion for additional injuries.***
- Analgesia as clinically indicated
- Prereduction films
  - Confirm dislocation classification.
  - Identify concomitant injuries.
  - Differentiate tibiotalar dislocations from distal tibial fractures or subtalar dislocation.
    - A subtalar dislocation is the disruption of the articulation of both the talocalcaneal and the talonavicular joints with an intact ankle joint mortis; this occurs in less than 1% of all dislocations.
- Reduction
  - Administer appropriate sedation.
  - Technique is dependent on dislocation classification.
  - Ideal reduction involves the clinician and two assistants.
- Repeat physical exam and neurovascular assessment
- Splinting
- Postreduction films
- Appropriate adjunctive measures and planning
  - Open fractures may require intravenous (IV) antibiotics, tetanus, vaccine, and/or surgical consultation.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- ***Open dislocations without evidence of acute neurovascular compromise should be managed operatively and forego emergency reduction***.

SPECIAL CONSIDERATIONS

- Clinical diagnostic challenges
  - Obesity
  - Significant edema
  - Cases of subtle dislocation
- Reduction challenges
  - Soft-tissue obstruction
  - Intraarticular bone fragments
- Open dislocations, neurovascular compromise
- Differentiation from subtalar dislocations

PROCEDURE PREPARATION

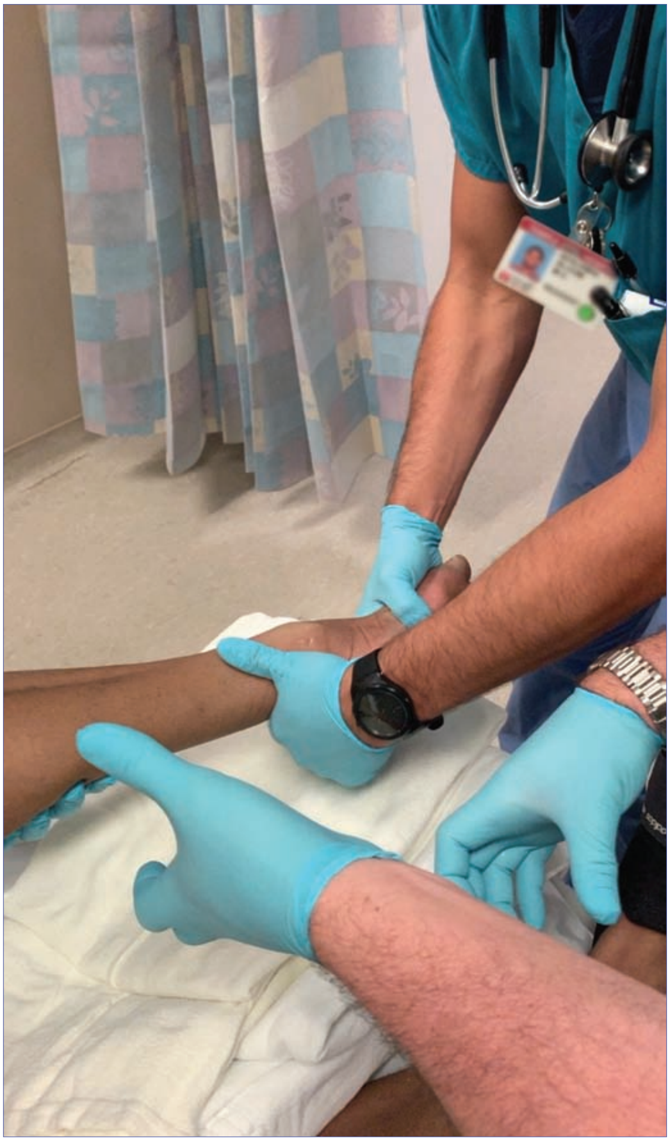
- All reductions require adequate analgesia and sedation.
  - Procedural sedation in the ED setting is typically preferred.
    - Ketamine, propofol, nitrous oxide, or an opioid plus benzodiazepine
- Ideal reduction technique involves the clinician and two assistants.
- Splinting material should be available for use immediately postreduction and be premeasured and ready to use.
  - Use the contralateral lower extremity for dimensions.

PROCEDURE

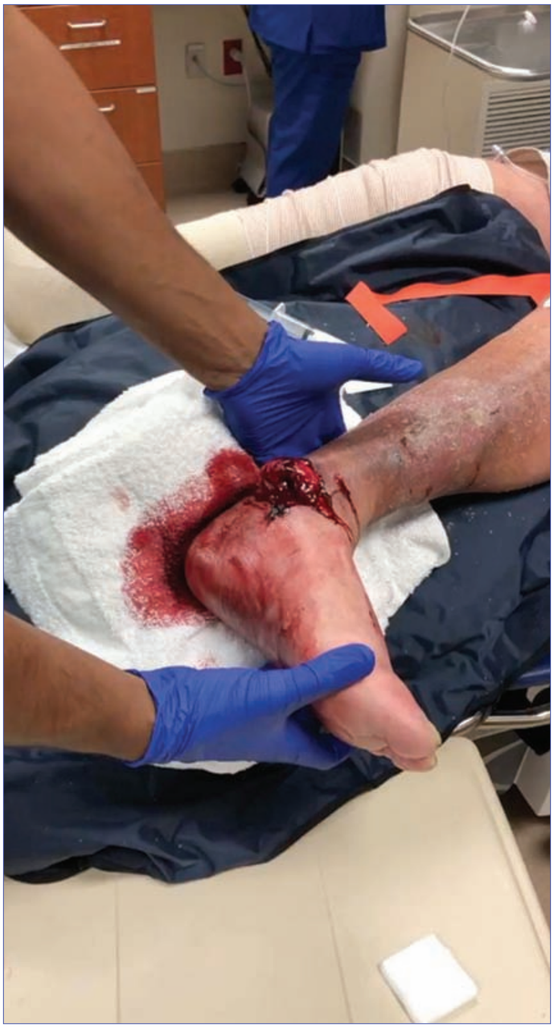
Reduction technique is similar for all dislocations; however, the direction of countertraction and reduction force applied are dependent on the type of injury. In general, as in any fracture and/or dislocation, one wants to engage in exaggeration of the injury, distraction, and then traction in this order.

Posterior Dislocation

- Patient position
  - Patient is supine with knee slightly flexed to relax the Achilles tendon/gastrocnemius.
  - Have the foot hanging off of the stretcher for better leverage.
- Countertraction
  - Assistant: Hands are on mid-calf; flex knee, and apply longitudinal traction.
  - Single clinician: Patient leg hangs off bed at the knee, or leg is propped up at the knee with pillows or a rolled blanket.
- Technique (**VIDEOS 56.1** and **56.2**)
  - Place one hand behind patient's heel, and one hand on the dorsum of the foot (**FIGURE 56.6**).
  - Plantar flex the foot (***exaggeration***).
  - Apply longitudinal, downward traction at the heel and pull the foot away from the tibia (***distraction***).
  - Dorsiflex foot and move it anteriorly, returning it to anatomical position (***traction***).
    - If a second assistant is available, they should apply *posterior* pressure at the distal tibia during this step (**FIGURE 56.7**).
  - Obtain postreduction x-rays (**FIGURE 56.8**).



VIDEO 56.1 Closed reduction of a tibiotalar dislocation.



VIDEO 56.2 Open tibiotalar dislocation with vascular compromise warrants immediate reduction and repeat check of neurovascular status. Being an open dislocation, immediate orthopedic consultation for surgical cleanout/repair and IV antibiotics are in order.

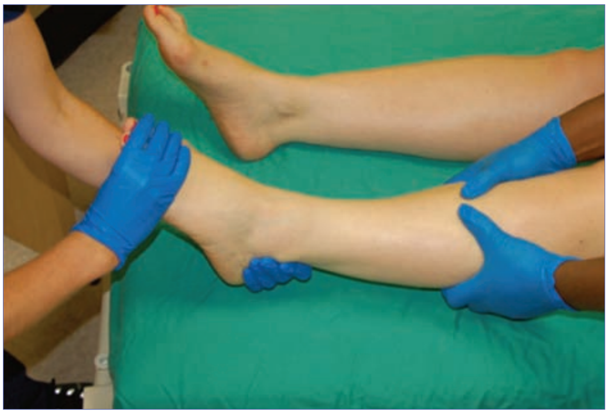


FIGURE 56.6 Closed reduction of tibiotalar dislocation. Plantar flex the foot and apply traction at heel while assistant provides countertraction.

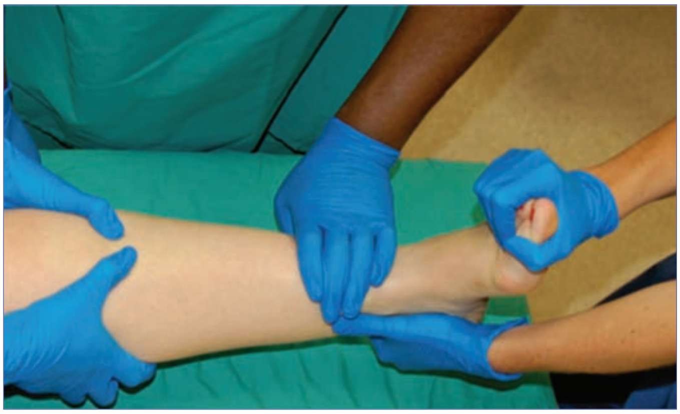


FIGURE 56.7 Dorsiflex the foot and move anteriorly while the second assistant applies posterior pressure.

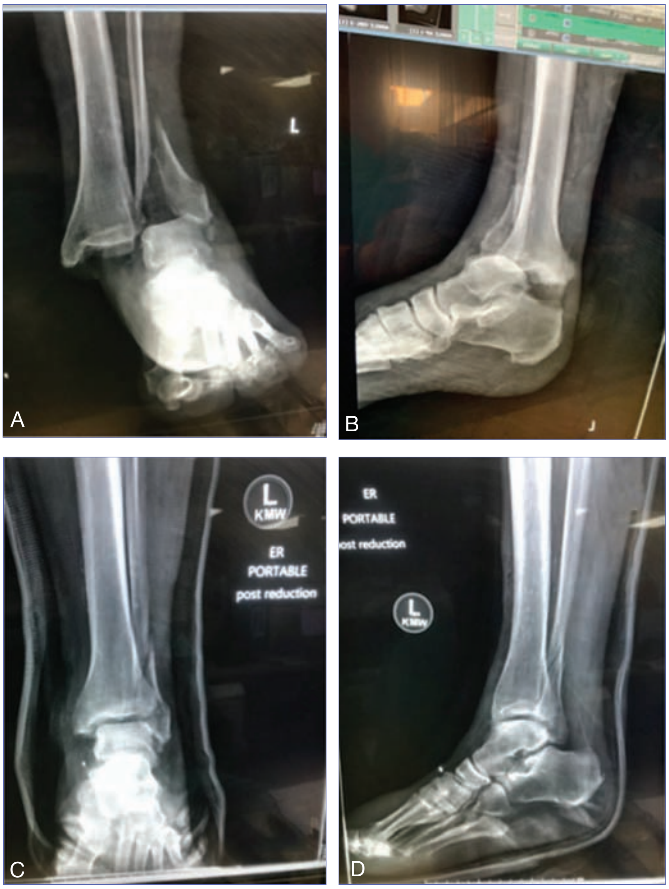


FIGURE 56.8 X-rays. (A and B) Pre- and (C and D) post-closed reduction. Notice the mortise completely disrupted by the fracture dislocation. Post-reduction and splinting ensure an adequate reduction with improved mortise configuration.

Anterior Dislocation

- Patient position
  - Patient is supine with knee slightly flexed to relax the Achilles tendon/gastrocnemius.
- Countertraction
  - Assistant: Hands are on mid-calf; flex knee, and apply longitudinal traction.
  - Single clinician: Patient leg hangs off bed at the knee, or leg is propped up at the knee with pillows or a rolled blanket.

- Technique
  - Place one hand behind the patient's heel, and one hand on the dorsum of the foot.
  - Dorsiflex the foot and apply longitudinal, downward traction at the heel to pull the foot away from the tibia.
  - Keep the foot at 90 degrees to the leg and move it posteriorly, returning it to anatomical position.
    - If a second assistant is available, they should apply *anterior* pressure at the distal tibia during this step.

Lateral and Medial Dislocation

- This is often associated with fracture.
- If open fracture, emergency reduction is not indicated and orthopedics should be immediately consulted for surgical management unless there is neurovascular compromise.
- If closed fracture, the reduction technique is similar to that of a posterior reduction except the foot is moved either medially (lateral dislocation) or laterally (medial dislocation) rather than anteriorly.

ULTRASOUND GUIDANCE

Ultrasound does not play a role in the reduction of ankle dislocations.

POSTPROCEDURE CONSIDERATIONS

- All reductions must be followed by:
  - Repeat physical exam; especially a neurovascular assessment
  - Splinting
    - Splint foot at 90 degrees in long-leg posterior splint +/− stirrup splint
    - Neurovascular assessment after splint placement
  - Postreduction films
- If neurovascular compromise is apparent after reduction, emergency operative management is indicated.

EDUCATIONAL POINTS

- Ankle dislocations are rare injuries usually occurring as a result of high-energy impact.
- Classification of dislocation is dependent on the direction of talar displacement.
- Examiner must assess for neurovascular compromise and/or open injury that would necessitate immediate orthopedic surgical consultation for possible operative management.
- Reduction of closed, uncomplicated dislocation should be performed with the use of analgesia and procedural sedation with multiple clinicians applying traction–countertraction based on the type of dislocation present.
- Postreduction care requires repeat neurovascular assessment and appropriate splinting.
- The fact that the medial and lateral ligaments are very robust structures explains the more common fractures associated with ankle injuries where bone fails under stress before ligaments.
- Expedient reduction of these injuries is of paramount importance to relieve the pressure on the neurovascular structures, avoid skin compromise, and to reduce swelling formation.
- Though true arterial injury (posterior tibial and dorsalis pedis artery) is exceptionally rare, when there is any doubt, the vascular surgeon must certainly be consulted and, if necessary, arteriography should be performed.

COMPLICATIONS

Several complications are associated with ankle dislocations. Fractures and ligamentous injuries, as outlined in **TABLE 56.1**, are common and prompt orthopedic evaluation. In addition, skin compromise is common with significantly displaced injuries. The clinician must be diligent in examining the skin for tenting, lacerations, blistering, and ulceration. Finally, vascular compromise is uncommon but can occur with significantly displaced injuries. If neurovascular compromise is apparent after reduction, emergency operative management is indicated.

PEARLS

- Careful inspection of the skin and a careful neurovascular exam are critical prior to reduction.
    - Open dislocations without neurovascular compromise should be managed operatively and forego emergency reduction.
        - Emergency management includes IV antibiotics and tetanus vaccine as indicated.
    - Neurovascular compromise and significant skin ischemia are indications for prompt reduction, possibly without prereduction films.
- Prereduction films are important to definitively differentiate talotibial dislocations from subtalar dislocations, which can present similarly but often require open reduction.
- Superior ankle dislocations are rare but, if present, should prompt high suspicion for concomitant spinal or calcaneal injury.
- Adequate pain control, sedation, and appropriate patient positioning are keys to successful reduction.
    - Keep the knee flexed to relax the gastrocnemius, soleus, and Achilles.
    - The help of two assistants is ideal.
- Failure of reduction may be due to soft-tissue obstruction or due to bone fragments displaced within the joint.

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CHAPTER

57

Procedures for Managing Nursemaid's Elbow

Emily Friend and Maura Sammon

BACKGROUND

Among infants and preschool children with complaints of upper extremity immobility, nursemaid's elbow or annular ligament subluxation/displacement is the most common cause presenting to pediatric EDs. The typical age of presentation for radial head subluxation (nursemaid's elbow) is 1 to 4 years, although cases have been reported from ages 6 months through 7 years. The avegare age is 28 months and is rare after the age of 5 years. The typical mechanism is that of a sudden longitudinal traction force applied to the arm with the elbow extended and the forearm slightly pronated. ***This mechanism is reported in 51% of cases, whereas 22% of patients will report a fall. Recurrence is common, with a reported rate of 20%***. Physiologically, the annular ligament stretches and tears at its attachment to the radial neck and slips between capitellum and radial head (**FIGURE 57.1**). ***The distal attachment of the annular ligament becomes stronger and the radial head grows wider at approximately 5 years of age, significantly reducing the prevalence of this injury among older children.***

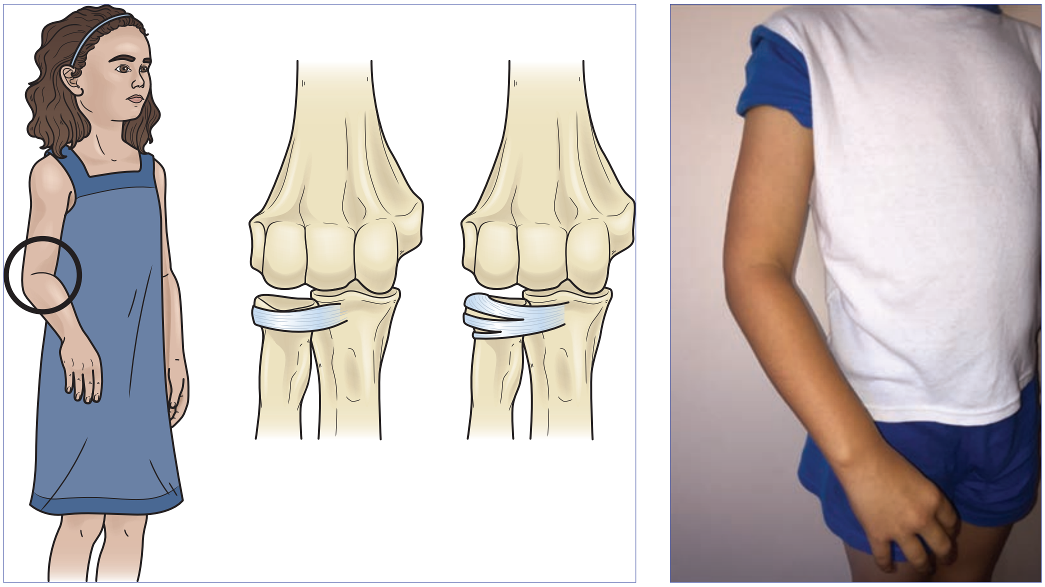


FIGURE 57.1 Note the arm is in slight flexion and the wrist is in pronation. Also note that the underlying pathology is not an "elbow dislocation" but rather a proximal displacement and entrapment of the annular ligament between the radial head and the capitellum. Finally, note the absence of swelling and distress typically found in fractures.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

PATIENT PRESENTATION

- Arm will be held in flexion and pronation (**FIGURE 57.1**).
- The child will often be in no acute distress.
- ***Swelling, ecchymosis, and deformity are absent***.
- There may be ***mild nonpoint tenderness*** to palpation.
- The child will resist supination although they will be able to fully flex and extend the elbow.

TREATMENT

Radial head subluxation should be reduced at the time of presentation. If the child presents with an absence of point tenderness or swelling and a classic or vague acute history of injury, a reduction may be done.

Radiographs

- X-rays need not be routinely obtained unless presentation is atypical and there is suspicion of fracture. Annular ligament subluxation does not appear on x-rays.

Ultrasound

Though not routinely done as literature is still emerging, point-of-care ultrasound (POCUS) can assist in the diagnosis and management of patients with clinical suspicion of annular ligament displacement (**FIGURE 57.2**). Because the supinator

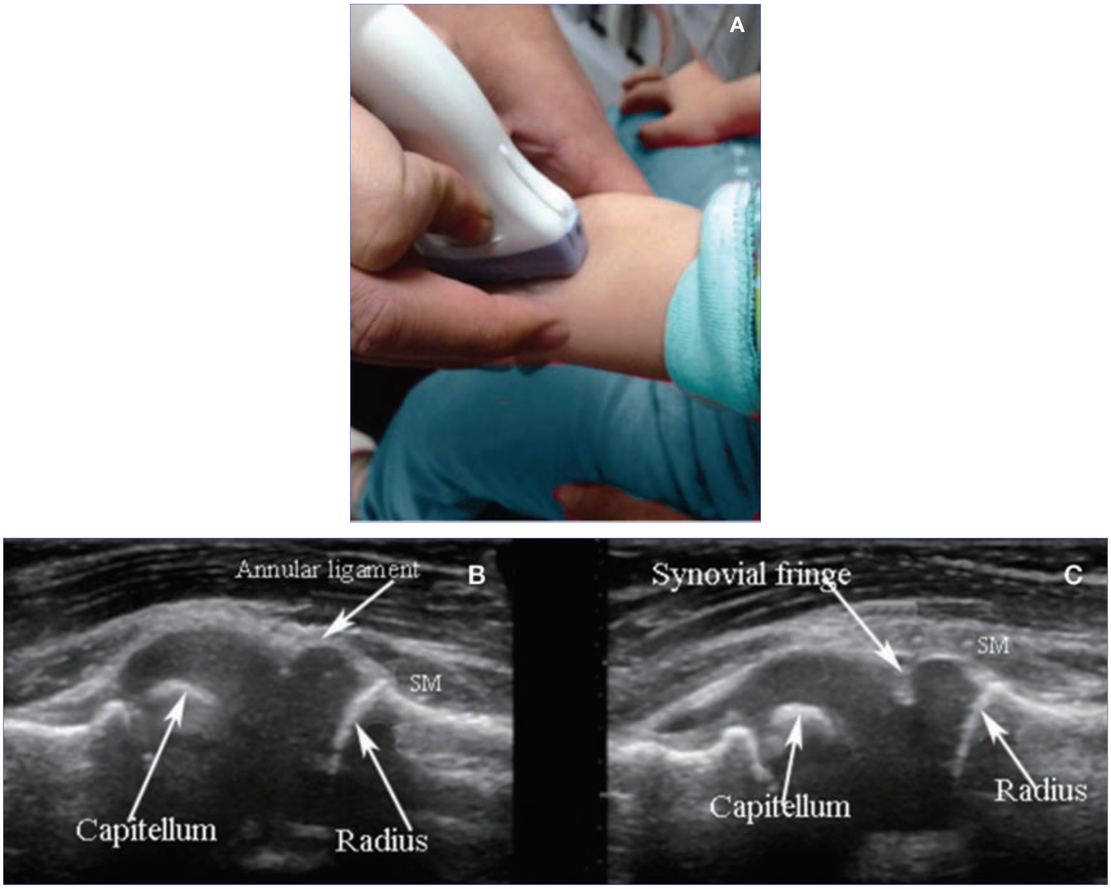


FIGURE 57.2 (A) Position of arm/elbow and probe; elbow is fully extended with the probe on the anterior portion of the capitellar–radial joint. (B) Contralateral arm's ultrasonographic image. We can see a normal supinator muscle and synovial fringe; the annular ligament is in place on the radius *(arrow)*. (C) Ipsilateral arm's ultrasonographic image; one visualizes enlargement of the synovial fringe because of the entrapped annular ligament, or hook sign.

SM, supinator muscle.

muscle often accompanies the annular ligament in slipping over the radial head, it is pulled proximally and entraps the radiohumeral (radio-capitellum) joint. By using POCUS, we usually find either:

- A change in shape of the supinator muscle
- The annular ligament not being over the radial head
- Enlargement of the synovial fringe of the annular ligament; this is also known as the *hook sign*

Lee et al. (2014) used retrospective POCUS to diagnose annular ligament subluxation in clinically diagnosed cases. Their results are shown in **TABLE 57.1**. Another less robust study of 70 patients published in the *Journal of Pediatric Orthopaedics* (Dohi, 2013) has shown the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) all to be 100% using POCUS.

Heydari et al. (2018) has demonstrated a sensitivity, specificity, and accuracy greater than 90% in determining successful postprocedure reductions, which can be applied to those cases that are not clinically obvious.

These findings may be subtle to the novice user; however, POCUS is an especially important modality in cases of possible fracture indicated by:

- Atypical presentations
- Inconclusive physical exams
- Unknown mechanism of injury

Kraus, Dongowski, Szalay, and Schnettler (2010) have shown that 11 cases of fractures were misdiagnosed as nursemaid's elbow over a 36-month period. Unclear clinical presentations are complicated by potentially unreliable history and physical exam in this age group.

Note that an enlarged posterior fat pad or lipohemarthrosis in the olecranon fossa are findings associated with fracture and this sonographic evidence may be of a higher sensitivity than x-rays (**FIGURES 57.3** and **57.4**).

TABLE 57.1 POCUS Sensitivity, Specificity, PPV, NPV of Detecting Annular Ligament Subluxation

Sensitivity	65%
Specificity	100%
PPV	100%
NPV	74%

NPV, negative predictive value; POCUS, point-of-care ultrasound; PPV, positive predictive value.

Source: Lee, Y. S., Sohn, Y. D., & Oh, Y. T. (2014). New, specific ultrasonographic findings for the diagnosis of pulled elbow. *Clinical and Experimental Emergency Medicine, 1*(2), 109–113. https://doi.org/10.15441/ceem.14.009

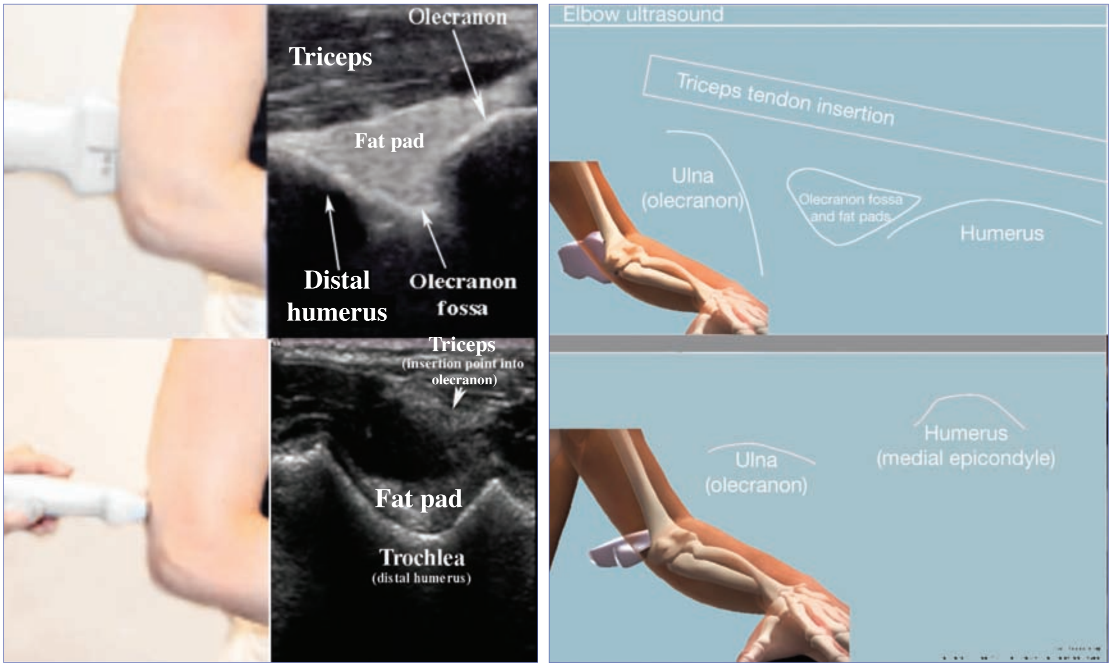


FIGURE 57.3 Longitudinal and transverse posterior views of the olecranon fossa. Note normal fat pads and the lack of anechoic fluid (lipohemarthrosis).
Generally look for olecranon fossa fluid proximal to the olecranon process; hence, it is better to start distally and work your way more proximally.

Source: Images on right side with permission from FPNotebook.com

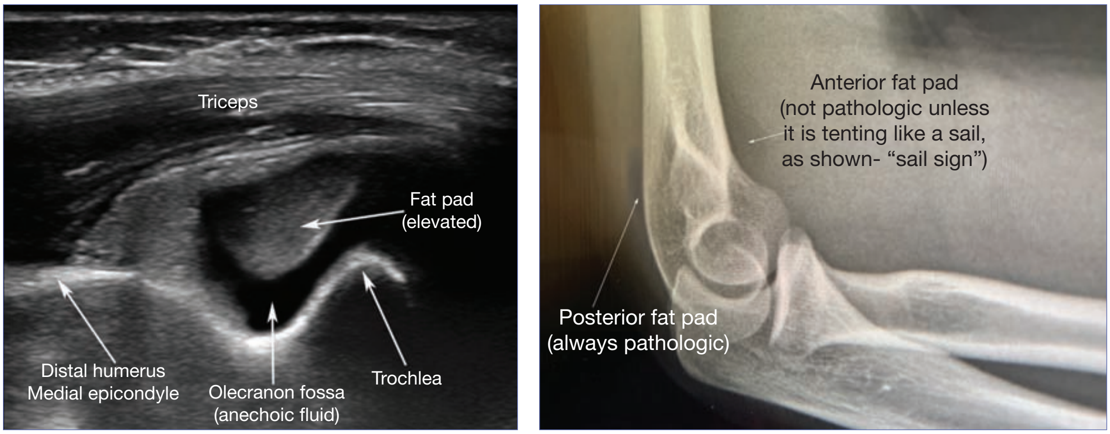

Triceps
Fat pad
(elevated)
Distal humerus
Medial epicondyle
Olecranon fossa
(anechoic fluid)
Trochlea
Anterior fat pad
(not pathologic unless
it is tenting like a sail,
as shown- "sail sign")
Posterior fat pad
(always pathologic)

FIGURE 57.4 Posterior longitudinal view of the elbow. Large olecranon fossa fluid collection (lipohemarthrosis) indicating a fracture in a patient presenting with a possible nursemaid's elbow. Patient exhibited point tenderness and an ambiguous history. X-ray shows the same fluid collection anteriorly and posteriorly displacing fat pads.

CONTRAINDICATION

- Suspicion of a fracture, septic arthritis, or other pathology

PROCEDURE PREPARATION

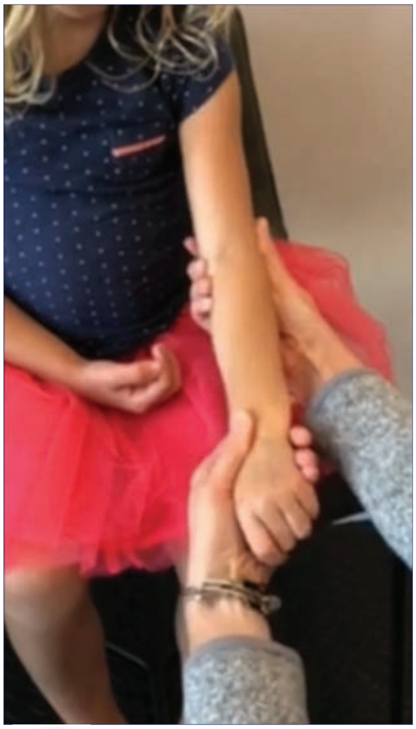
- Place the child in the parent's lap with the parent holding the ipsilateral humerus in adduction.
- Demonstrating the procedure with the unaffected upper extremity may alleviate parental and/or patient anxiety.

PROCEDURE

The annular ligament can be reduced by either hyperpronating or hypersupinating the wrist. A 2017 Cochrane review (Krul, van der Wouden, Kruithof, van Suijlekom-Smit, & Koes, 2017) demonstrated low-quality evidence in support of the hyperpronation method, with less failure at first attempt than supination-flexion, with a number needed to treat (NNT) of 6 (9.2% vs 26.4% failure rate). Classically, a "click" is heard or palpated upon successful reduction, with a PPV of 90% and NPV of 76%. The child should be observed using the arm fully within 5 to 10 minutes following the reduction. The clinician may attempt a second reduction if there is no use of the extremity after 30 minutes of observation.

Pronation Method

- Place pressure on the radial head with the thumb of one hand and then grasp the wrist with the other hand (**FIGURE 57.5A**).
- Hyperpronate the forearm using the hand holding the patient's wrist (**FIGURE 57.5B**) until a "click" is heard or reduction is felt (**VIDEO 57.1**).
- Immediately flex the elbow completely to the ipsilateral shoulder while maintaining radial head pressure (**FIGURE 57.5C**).



VIDEO 57.1 Pronation method: annular ligament reduction.

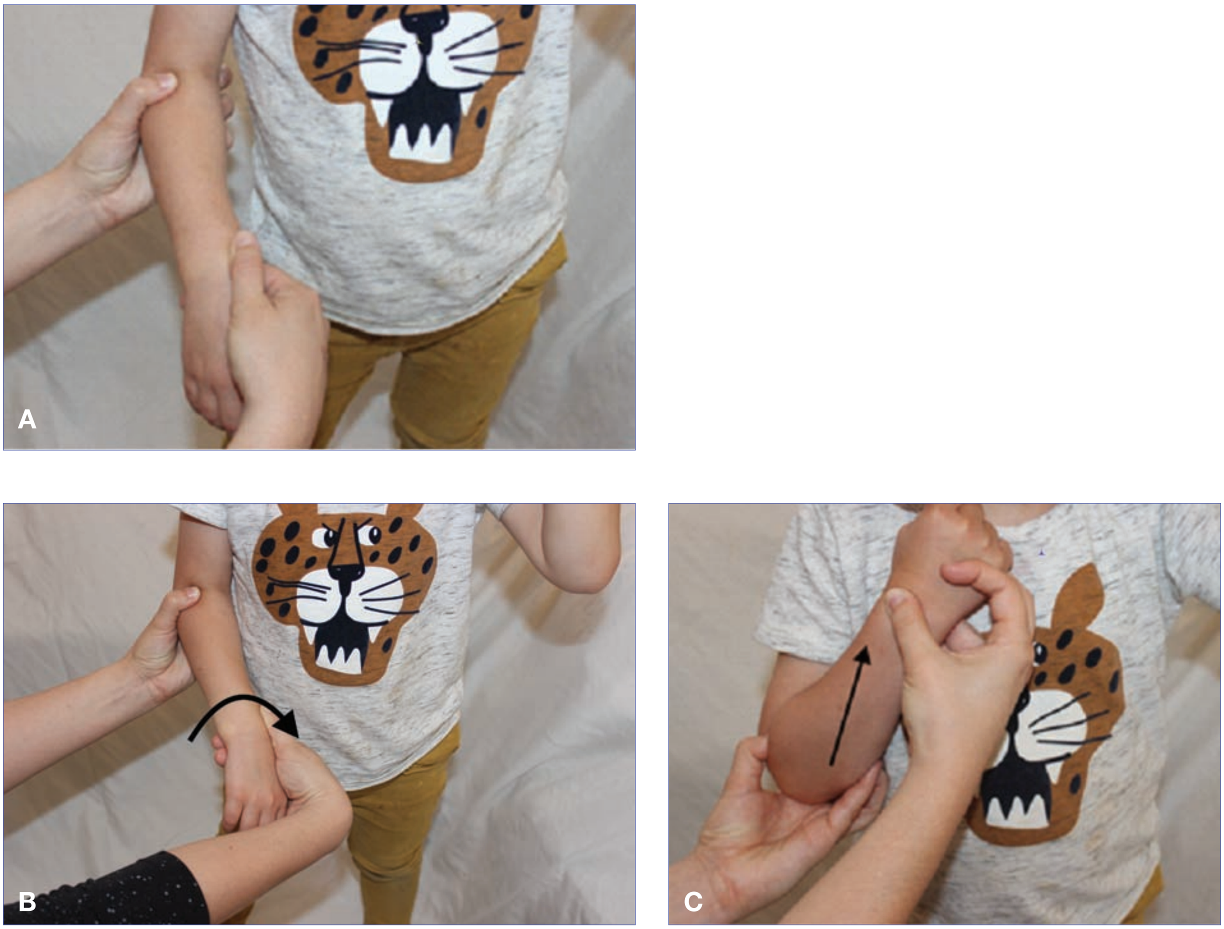


FIGURE 57.5 Pronation method. (A) Place pressure on the radial head with the thumb of one hand and then grasp the wrist with the other hand. (B) Fully pronate the wrist while maintaining pressure on the radial head. (C) Flex the elbow completely to the ipsilateral shoulder while maintaining radial-head pressure.

Supination Method

- Place pressure on the radial head with the thumb of one hand and then grasp the wrist with the other hand (**FIGURE 57.6A**).
- Fully supinate the forearm using the hand holding the patient's wrist while maintaining pressure on the radial head with the other hand (**FIGURE 57.6B**).
- Immediately flex the elbow completely to the ipsilateral shoulder while maintaining radial-head pressure (**FIGURE 57.6C** and **VIDEO 57.2**).

Differential Diagnosis

- Fracture
  - The child will demonstrate point tenderness with localized swelling; radiographs should be obtained for any patient with an atypical presentation or exam.
    - Supracondylar fracture is the most critical diagnosis to exclude prior to reduction.
- Septic arthritis
- Osteomyelitis

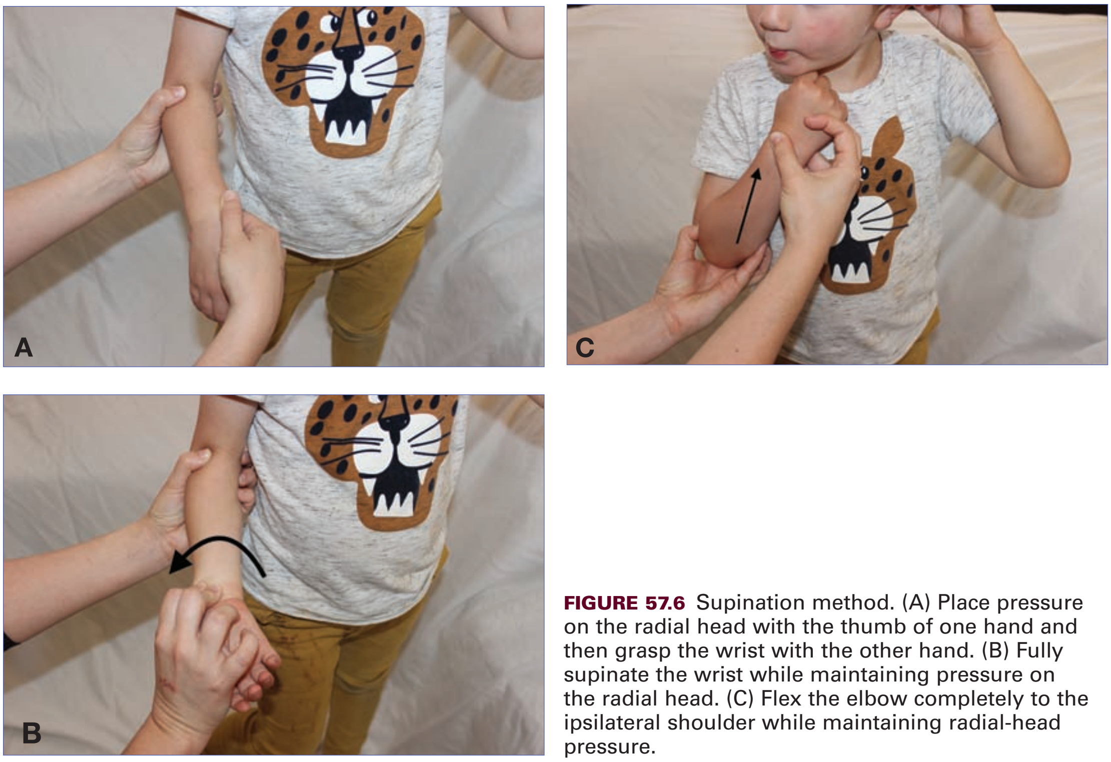


FIGURE 57.6 Supination method. (A) Place pressure on the radial head with the thumb of one hand and then grasp the wrist with the other hand. (B) Fully supinate the wrist while maintaining pressure on the radial head. (C) Flex the elbow completely to the ipsilateral shoulder while maintaining radial-head pressure.

VIDEO 57.2 Supination method: annular ligament reduction.

POSTPROCEDURE CONSIDERATIONS

If the child is using the arm normally and without pain when the clinician returns in 5 to 10 minutes, the reduction has been successful. After successful reduction, no immobilization is necessary in most cases. Children with recurrent episodes should be referred to an orthopedic surgeon.

If a reduction attempt is unsuccessful, the alternate reduction technique should be attempted. If multiple attempts using each technique are unsuccessful, radiographs should be obtained to rule out other injury. If no other injury is identified, immobilize the elbow with a posterior splint or sling and arrange orthopedic follow-up.

PEARLS

- If the first method fails, the second method should be attempted.
- Decrease apprehension by mimicking the technique first on the contralateral extremity.
- As per the literature, we recommend the pronation method first, followed by the supination method if need be.
- Use POCUS on ambiguous presentations and look for fluid (lipohemarthrosis) as indirect evidence of a fracture.
- If multiple attempts are unsuccessful, radiographs should be obtained.
- If child shows extreme anxiety, have parent palpate areas of concern and hence be the hands of the clinician.
- If diagnosis is confirmed but reduction unsuccessful, place the patient in a posterior splint or sling, and arrange orthopedic follow-up.

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CHAPTER

58

Procedures for Splinting Extremities

Saloni Malik, Naomi Rosenberg and Keith Lafferty

BACKGROUND

Splints are devices used to immobilize injured extremities in the acute setting. Splints accomplish the following: mechanical stabilization of fractures and dislocations, protection of injured soft tissue, pain control, and protection of the injured area from further trauma. Unlike formal casting, splints accommodate swelling without the risk of fixed external compression during a phase when soft-tissue swelling may be ongoing, while offering similar short-term immobilization. In addition, the patient can remove this device to perform wound care, allow range of motion, and allow continued hygiene.

PATIENT PRESENTATION

- Trauma resulting in fracture and/or dislocation
- Tendon pathology (laceration, tenosynovitis)
- Joint pathology (arthropathies, overlying lacerations)
- Ligamentous injury (sprains)

TREATMENT

Splints can be made either from plaster or fiberglass, with concurrent use of a stockinette, rolled cotton padding, and gauze or an elastic roll, or from prefabricated splinting material that contains the aforementioned components in one apparatus.

Plaster splinting material is more malleable than fiberglass and therefore more easily manipulated into certain shapes, is easier to cut with simple scissors or trauma shears, and in some cases will be less bulky and uncomfortable for the patient. However, it does require the measurement and assembly of more components. Wet plaster creates more mess than fiberglass, and improperly disposed of plaster can clog drains and hence requires specific drain traps. Unlike prefabricated fiberglass, which holds its shape, plaster is more prone to wrinkles and imperfections if not applied properly.

Prefabricated fiberglass offers an advantage over plaster in that it is stronger, lighter, easier to apply in some cases, cures more rapidly, and does not require specific drain traps in the sink. Prefabricated fiberglass is prewrapped in soft padded material, which reduces the number of steps in application of the splint. However, it is less malleable than plaster, and so may be less suited to splints requiring a precise shape. It also must be stored in airtight bags, as exposure to air will cause it to harden and become unusable.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Open fracture requires the attention of an orthopedic surgeon prior to definitive splinting.
- Compartment syndrome requires an orthopedic surgery consultation prior to definitive splinting.
- If the splint will obscure the area of injury, clinical suspicion requires neurovascular and compartment checks.
- Splinting is contraindicated if unaddressed soft-tissue wounds exist.
- Splinting is contraindicated if traumatic injury or illness requires more immediate intervention.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

SPECIAL CONSIDERATIONS

Compartment Syndrome

Although the most common cause of compartment syndrome is fracture, followed by blunt trauma, one must be aware that the most dreaded of complications in regard to splinting of an extremity is iatrogenic compartment syndrome. This cannot be overstated: Astute and meticulous splinting, along with the prevention of overzealous wrapping with elastic wrap, are paramount in avoiding this complication. Note the following critical times with regard to muscle and nerve injury/death (**TABLES 58.1** and **58.2**):

Compartment syndrome is historically taught as the five Ps (**TABLE 58.3**; pallor not shown in the table):

- Pain
  - Earliest sign is pain elicited by passive stretch of a muscle group traversing a given compartment.
  - Deep ache is often out of proportion to the injury and/or examination.
- Paresthesia
  - Later finding
    - Occurs after 75 minutes
  - Peripheral nerves most susceptible
- Pulselessness
  - Rarely present
  - Late finding
  - Usually the result of a direct vascular injury rather than compartment syndrome itself
  - Angiography may be indicated
- Pallor
  - Rarely present
- Paralysis
  - Very late finding

TABLE 58.1 Duration of Time Until Muscle Damage Occurs

Time (hours)	Damage
4	Reversible
6	Variable
8	Irreversible

TABLE 58.2 Duration of Time Until Nerve Damage Occurs

Time (hours)	Damage
2	Reversible
4	Neuropraxia
8	Irreversible

TABLE 58.3 Sensitivity, Specificity, PPV, and NPV of Classic Symptoms and Signs of Compartment Syndrome

	Pain	Paresthesia	Pulse	Paralysis
Sensitivity	0.19	0.13	0.19	0.13
Specificity	0.97	0.98	0.97	0.97
PPV	0.14	0.15	0.14	0.11
NPV	0.98	0.98	0.98	0.98

NPV, negative predictive value; PPV, positive predictive value.
Note: Pallor is a late finding and rare; hence, not included.

The most reliable signs of compartment syndrome are pain on passive stretching and tenderness upon palpation of the muscle compartment. Keep in mind that pain is the only early finding. Waiting for the other Ps almost guarantees irreversible cell death. The point regarding sensory loss in the distribution of the nerves transversing the affected compartment is important as many authors state that the most reliable physical finding of compartment syndrome is a sensory deficit, as these sensory nerves are more vulnerable to increasing pressures in a given compartment in regard to ischemia than are motor neurons and muscle. No doubt, two-point discrimination (which measures sensory loss) is a sensitive sign in differentiating compartment syndrome from benign raised intracompartment pressure alone, which does not elicit any ischemia.

- The normal pressure within any given compartment is between 0 mmHg to 8 mmHg.
  - *An intracompartmental pressure greater than 30 mmHg indicates compartment syndrome and a need for an emergenct fasciotomy.*
- A more accurate way to diagnose this pathologic and time-sensitive entity is to think in terms of the perfusion pressure of a given compartment, also known as the *compartment delta pressure*.
- The compartment delta pressure is defined as the difference between the diastolic blood pressure and the intracompartmental pressure.
- **Delta pressure = Diastolic pressure – Measured intracompartmental pressure**
  - *A delta pressure less than or equal to 30 mmHg is indicative of the need for fasciotomy.*
  - McQueen and Court-Brown (1996) have shown prospectively that using the delta pressure formula led to no compartment syndromes being missed, whereas Ozkayin and Aktuglu (2005) avoided 30 unnecessary fasciotomies.

If compartment syndrome is suspected, measuring the pressure within a given compartment is easily accomplished with today's equipment (**FIGURES 58.1** and **58.2** and **VIDEO 58.1**). Remember, fascia is a thin, inelastic sheet of connective tissue that surrounds muscle compartments and limits the capacity for rapid expansion. Also, keep in mind that the diagnosis should be made upon determination of the earliest of the Ps, that is, pain. Waiting for the other later P findings will cause a delay in diagnosis (elevating compartment pressures) and treatment (removal of sling/bivalve of splint/fasciotomy). Although a full discussion of compartment syndrome is beyond the scope of this chapter, note the following patient who returned the next day after an overardent elastic wrap/splint was placed on a forearm secondary to a mild blunt-trauma mechanism (**VIDEO 58.2**).

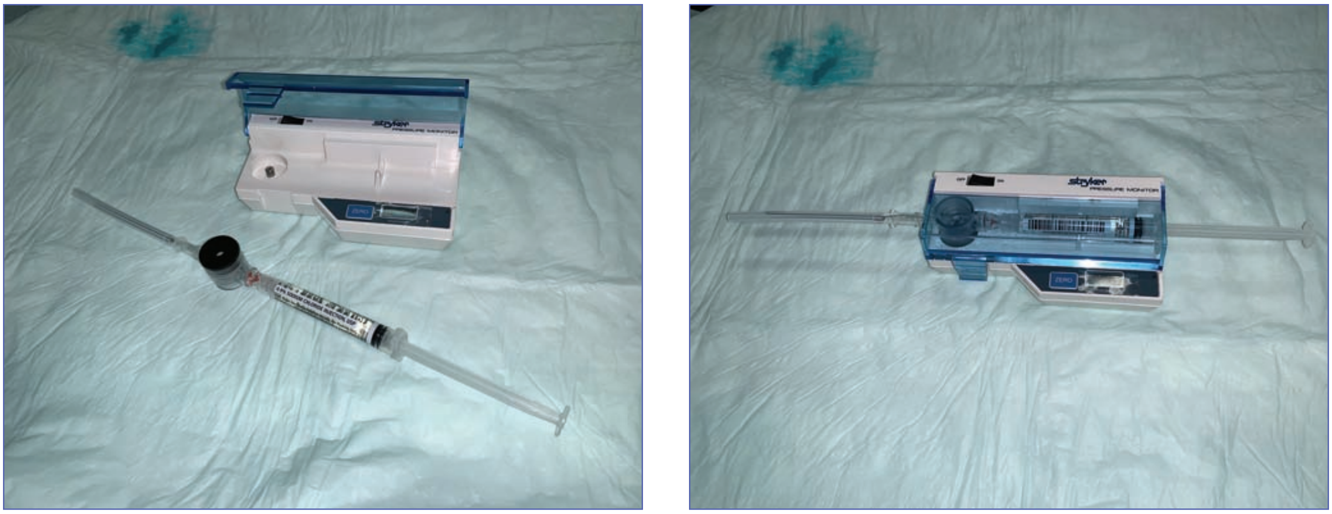


FIGURE 58.1 Commercial hand-held digital manometer for measuring intracompartmental pressures. This is a Stryker device, which is easy to use.

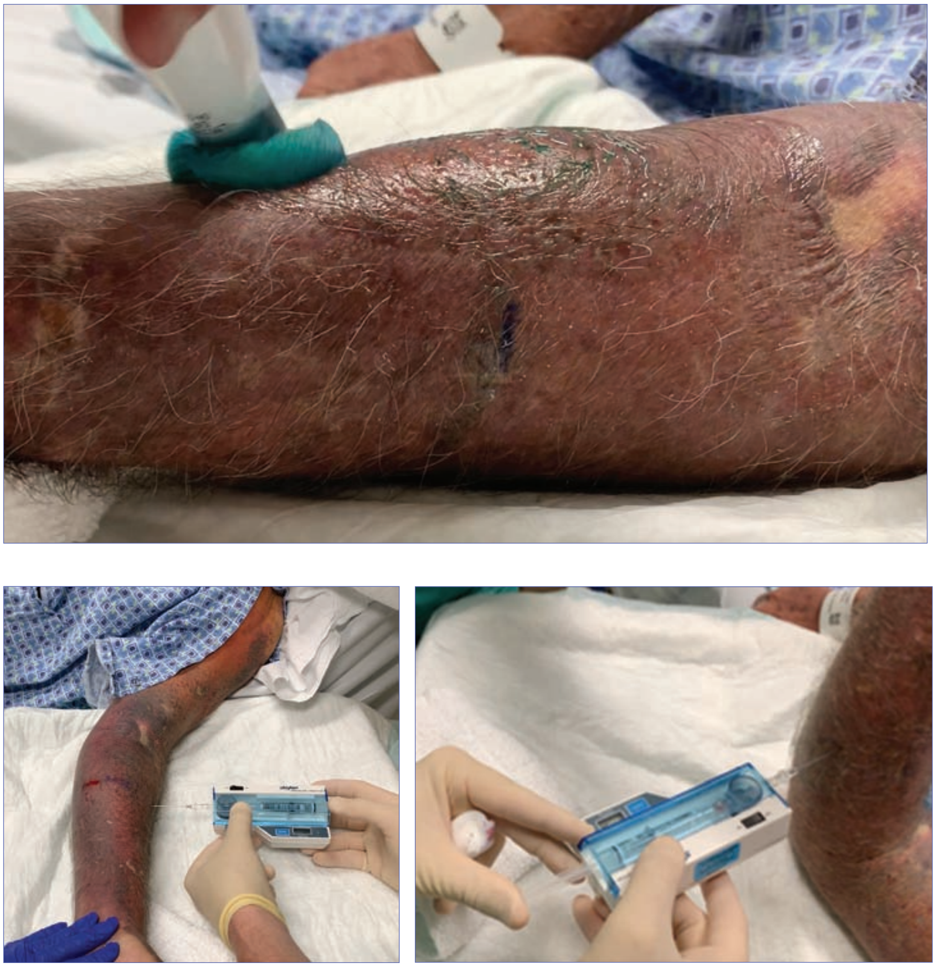
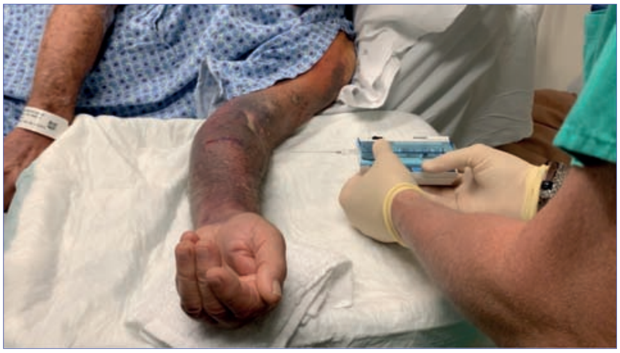


FIGURE 58.2 Measuring the various compartments of the forearm.



VIDEO 58.1
Compartment pressure
measurement technique.

PROCEDURE PREPARATION

The first step of splint application is gathering supplies and measuring the extremity. ***Proper measurement can be performed on the contralateral extremity using an elastic wrap, length of stockinette, or undercast padding to approximate the length.*** While measuring, position the extremity in the desired splint position. In general, the position of the joint being splinted should be as listed in **TABLE 58.4**.

- Supplies
  - Stockinette
  - Undercast padding
  - Elastic bandage roll
  - Plaster or prefabricated splinting material
  - Access to water
  - Scissors or shears (for trimming)

VIDEO 58.2 Emergent fasciotomy in the operating room.

PROCEDURE

General Approach to Splinting

Position the injured extremity as desired for the splint, using an additional person to help hold the extremity in position if necessary. ***Lower extremity splints are often most easily applied with the patient in the prone position.*** Next, confirm that splint supplies have been accurately measured before beginning application. Please see **TABLES 58.5** and **58.6** for splint specifications by indication.

If using plaster, create a splint of desired length using eight to 10 layers for upper extremities, and 10 to 12 layers for lower extremities. After applying water to the plaster and squeezing out excess moisture, sandwich the wet plaster between two lengths of rolled cotton padding. The plaster should be entirely contained within the padding. If using prefabricated material, apply a small amount of water to the splint, squeezing out excess moisture.

TABLE 58.4 Positioning of Joint for Splint Application

Joint	Position
Elbow	90-degree flexion with forearm in neutral position, “thumbs up”
Wrist	Slight extension of 20 degrees*
Thumb	Abducted*
MCP joints	Flexed at 60 degrees*
PIP joints	Slightly flexed at 10–20 degrees*
DIP joints	Slightly flexed at 5 degrees*
Ankle	90 degrees of dorsiflexion
Knee	Minimal flexion

*Positioned as if the patient is holding a bottle of beer, also known as the *position of function*.
DIP, distal interphalangeal; MCP, metacarpophalangeal; PIP, proximal interphalangeal.

Apply a stockinette (slightly longer than the length of the splint) to the extremity. Next, ***pad bony prominences with undercast padding.***

Apply the moistened splint to the extremity, contouring it to the desired position. Wrap an elastic wrap around the extremity as the splint dries. The splint is thus contoured into the proper position and held until fully hardened. When applying the splint, care should be taken to avoid the following:

- Creation of sharp edges or wrinkles
- Excessive pressure points that could lead to skin ulcerations
- Circumferential application of the splint around the extremity
- Excessively tight wrapping of the elastic bandage (**FIGURE 58.3**)
- Bunching of the elastic bandage

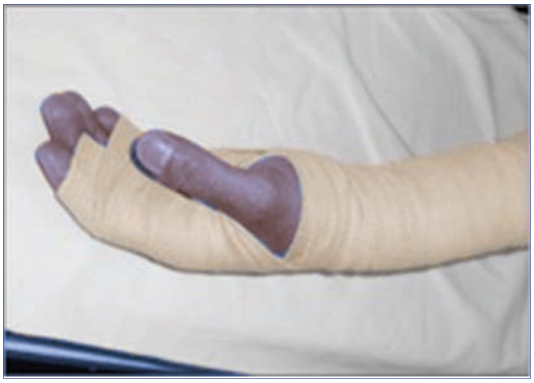


FIGURE 58.3 Inappropriately tight elastic bandage wrap.

The potential of a splint for inducing ischemia is much less likely than that of a cylindrical cast, although it can still occur. It is imperative not to apply an elastic bandage too tightly. The patient should be instructed as to signs of excessive compression and to loosen the elastic bandage if this occurs.

TABLE 58.5 Types of Upper Extremity Splints

Type and Indication	Length	Width	Note
Volar (**FIGURES 58.4**, **58.5**, and **VIDEO 58.3**) Forearm, wrist, metacarpal fractures/injuries	Proximal fingers to just below the elbow on anterior surface	Fully covers the forearm	Allows supination and pronation of the forearm; this should not be used for the treatment of ulnar or radial fractures

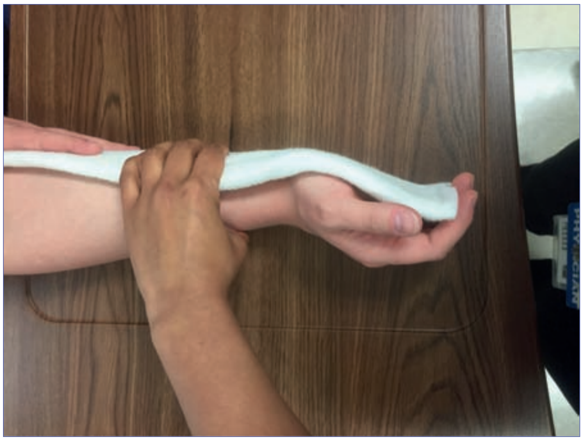


FIGURE 58.4 Volar splint application. Positioning for Volar splint. Note this is often a two-person procedure.

Volar Short Arm
Splint Application Technique

VIDEO 58.3 Volar splint application.

Source: Proliance Orthopaedics & Sports Medicine. (2019). *Volar short arm splint* [Video file]. Retrieved from https://youtu.be/xekSpaAobAI

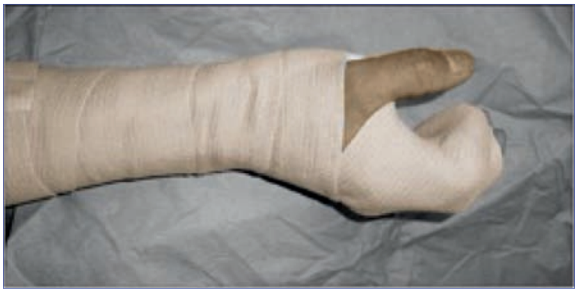


FIGURE 58.5 Completed volar splint.

TABLE 58.5 Types of Upper Extremity Splints (*continued*)

Type and Indication	Length	Width	Note
Sugar tong (**FIGURES 58.6**, **58.7**, and **VIDEO 58.4**) Distal radius and ulnar fractures/ injuries	Metacarpal heads on dorsal hand and around the elbow extending over anterior forearm to just distal to the MCP joints	Forearm width without overlap of volar and dorsal surfaces	Treatment of choice because it diminishes supination/ pronation of the forearm

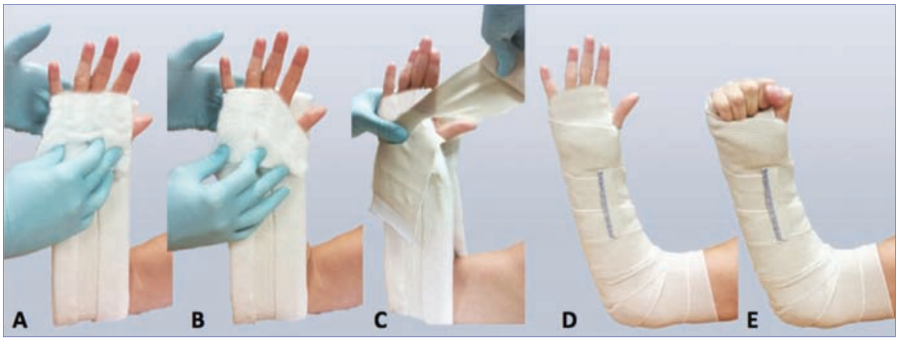


FIGURE 58.6 Application of sugar-tong splint.

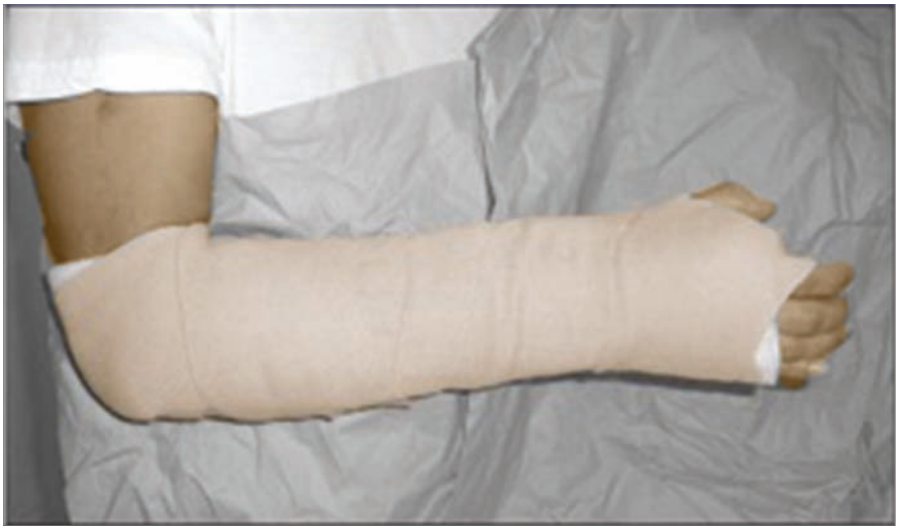


FIGURE 58.7 Completed sugar-tong splint. Sling not shown.

Sugar Tong
Splint Application Technique

VIDEO 58.4 Sugar-tong splint application.

Source: Proliance Orthopaedics & Sports Medicine. (2019). *Sugar tong splint* [Video file]. Retrieved from https://youtu.be/MaCo4hbcMv4

TABLE 58.5 Types of Upper Extremity Splints (*continued*)

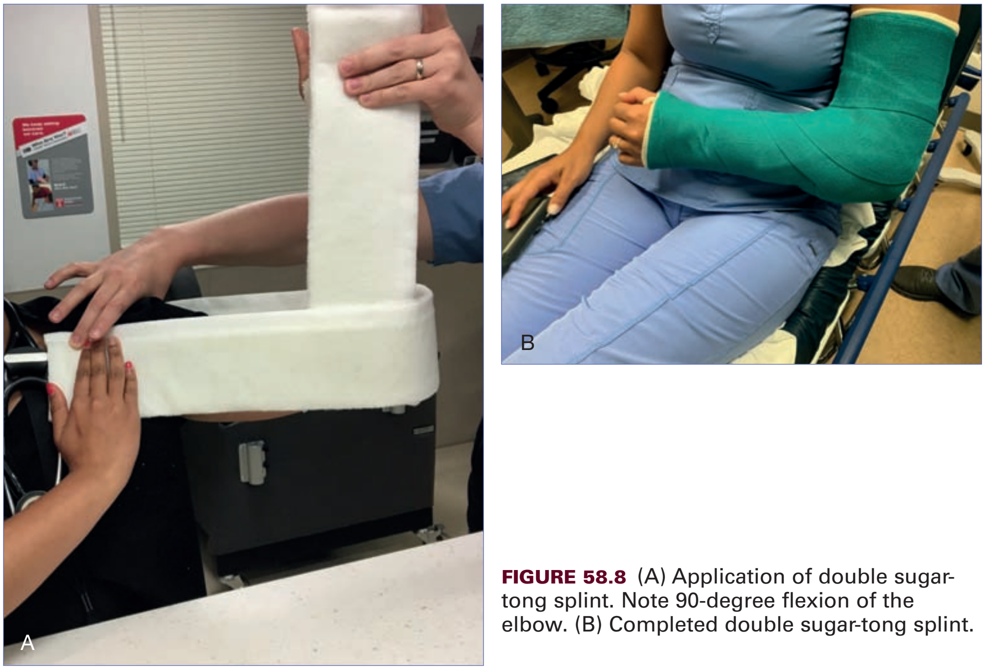
<table>
<tr><th>Type and Indication</th><th>Length</th><th>Width</th><th>Note</th></tr>
<tr><td>Double sugar tong
(FIGURE 58.8)
Elbow and forearm fractures/injuries</td><td>Lateral proximal humerus around elbow to the medial humerus up to the inferior axilla</td><td>Fully covers the dorsal and volar upper arm without overlap</td><td>The forearm component is applied exactly as for the single sugar tong; this device prevents pronation/supination of the forearm more so than does the single sugar tong and posterior splint; apply forearm portion before upper arm portion</td></tr>
<tr><td colspan="4">

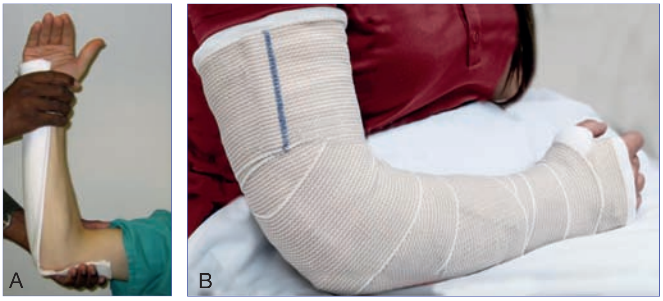
FIGURE 58.8 (A) Application of double sugar-tong splint. Note 90-degree flexion of the elbow. (B) Completed double sugar-tong splint.</td></tr>
<tr><td>Long arm posterior
(FIGURE 58.9 and VIDEO 58.5)
Stable elbow and forearm fractures/injuries</td><td>Dorsal aspect of midupper arm under elbow along the ulnar area of the forearm to the distal palmar flexor crease</td><td>Half the arm circumference</td><td>Allows some supination/pronation of forearm</td></tr>
<tr><td colspan="4">

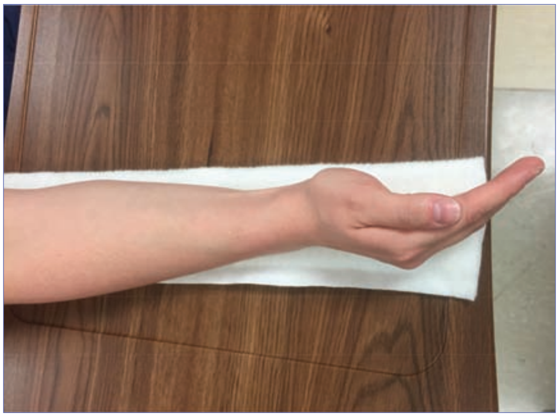
FIGURE 58.9 Application of long arm posterior splint. (A) Note 90-degree flexion of the elbow. (B) Completed long arm posterior splint.</td></tr>
</table>

(*continued*)

TABLE 58.5 Types of Upper Extremity Splints (*continued*)

<table>
<tr><th>Type and Indication</th><th>Length</th><th>Width</th><th>Note</th></tr>
<tr><td colspan="4">

Splint - Proliance Orthopaedics & Sports ...
LIANCE PAEDICS SPORTS EDICINE
Long Arm Posterior
Splint Application Technique

VIDEO 58.5 Long arm posterior splint application.
Source: Proliance Orthopaedics & Sports Medicine. (2019). *Posterior long arm splint* [Video file]. Retrieved from https://youtu.be/kXyGlqvYWts</td></tr>
<tr><td>**Ulnar gutter** (**FIGURES 58.10, 58.11**, and **VIDEO 58.6**)
Fourth/fifth metacarpal and proximal phalangeal fractures/injuries</td><td>Just beyond the fifth DIP joint to midforearm along the ulnar surface</td><td>Midline of hand on the dorsal and volar surface incorporating both the little and ring fingers</td><td>Gauze should be placed between the fourth and fifth fingers</td></tr>
<tr><td colspan="4">
FIGURE 58.10 Application of ulnar gutter splint. Note the position of function of the hand (mimicks holding a bottle of beer).

PROLIANCE ORTHOPAEDICS & SPORTS MEDICINE
Ulnar Gutter
Splint Application Technique

VIDEO 58.6 Ulnar gutter splint application.
Source: Proliance Orthopaedics & Sports Medicine. (2019). *Ulnar gutter splint* [Video file]. Retrieved from https://www.youtube.com/watch?v=lJPlgQ_TW1Q&feature=youtu.be

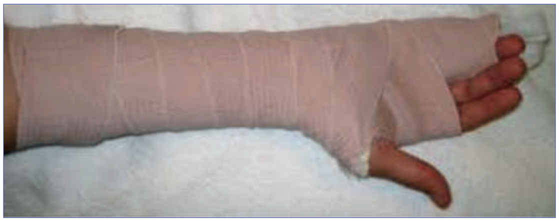



FIGURE 58.11 Completed ulnar gutter splint.</td></tr>
</table>

(*continued*)

TABLE 58.5 Types of Upper Extremity Splints (*continued*)

Type and Indication	Length	Width	Note
Radial gutter **(FIGURES 58.12 and 58.13)** Phalangeal and metacarpal fracture and/or soft-tissue injuries of the second and third digits	Just beyond the second and third DIP joint with thumb free	Width of posterior 3/5 of forearm	Gauze should be placed between the second and third fingers

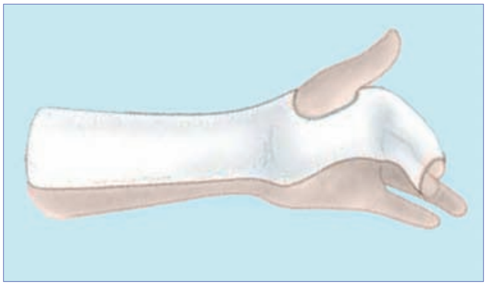


FIGURE 58.12 Application of radial gutter splint.

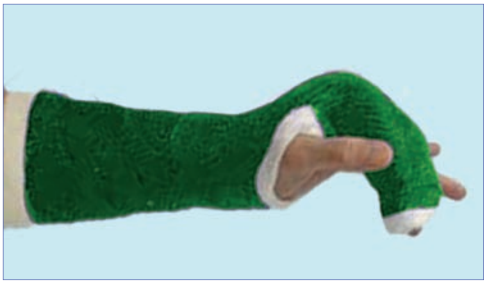


FIGURE 58.13 Radial gutter splint. As with the ulnar gutter splint, note the position of function of the hand.

Thumb spica **(FIGURE 58.14 and VIDEO 58.7)** First metacarpal, proximal first thumb, phalangeal and scaphoid fracture/injuries De Quervain tenosynovitis	Just distal to the interphalangeal joint of the thumb to the midforearm along the radial surface	The width of the wrist	Splint all suspected scaphoid injuries as up to 10% of these fractures are missed on initial presentation

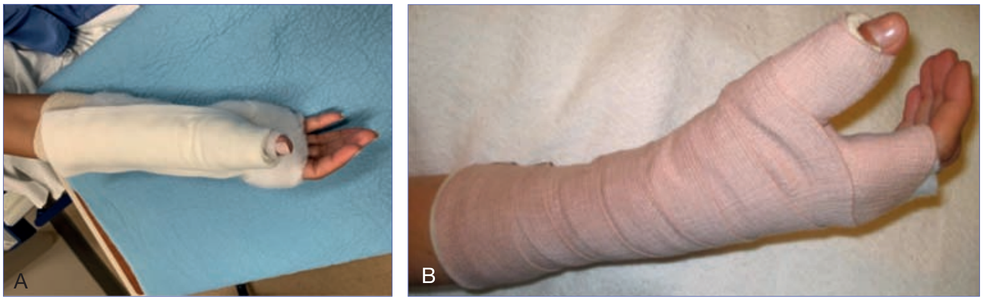


FIGURE 58.14
(A) Application of thumb spica splint.
(B) Completed thumb spica splint. Note hitchhiker thumb positioning.

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PROLIANCE ORTHOPAEDICS & SPORTS MEDICINE
Thumb Spica
Splint Application Technique

VIDEO 58.7 Thumb spica splint application.

Source: Proliance Orthopaedics & Sports Medicine. (2019). *Thumb spica splint* [Video file]. Retrieved from https://youtu.be/vQfy7YJsglk

(*continued*)

TABLE 58.5 Types of Upper Extremity Splints (*continued*)

Type and Indication	Length	Width	Note
Finger splint (**FIGURE 58.15**) Phalanx fractures, tendon repairs/infections, and arthropathies	No further than the joint below or above the injury	Width of finger	DIP dislocations—The joint should be splinted in slight extension or no more than 5 degrees of flexion. PIP dislocations—The joint should be at 20 degrees of flexion. Mallet finger is a distal extensor tendon rupture; immobilization of only the DIP joint is required. Apply splint to dorsal surface because this maintains tactile function and is in closer proximity to the bone on the surface. Commercially available padded aluminum splints can easily be cut to length; avoid or cover sharp aluminum edges.

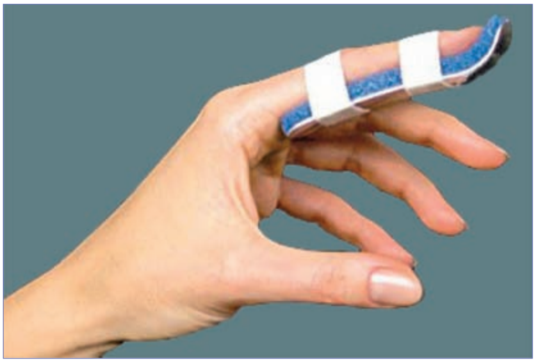


FIGURE 58.15 Completed finger splint.

DIP, distal interphalangeal; MCP, metacarpophalangeal; PIP, proximal interphalangeal.

Note figure cites next to each splint type.

Lower Extremity Splints

TABLE 58.6 Type of Splints

Type and Indication	Length	Width	Note
Short posterior leg (**FIGURES 58.16**, **58.17**, and **VIDEO 58.8**) Distal tibia, fibula, ankle, and foot fractures/injuries	Posteriorly from the level of the fibular neck, around the heel to the base of the toes	Covers half the leg circumference	When this is combined with the stirrup splint, it gives increased lateral ankle support.

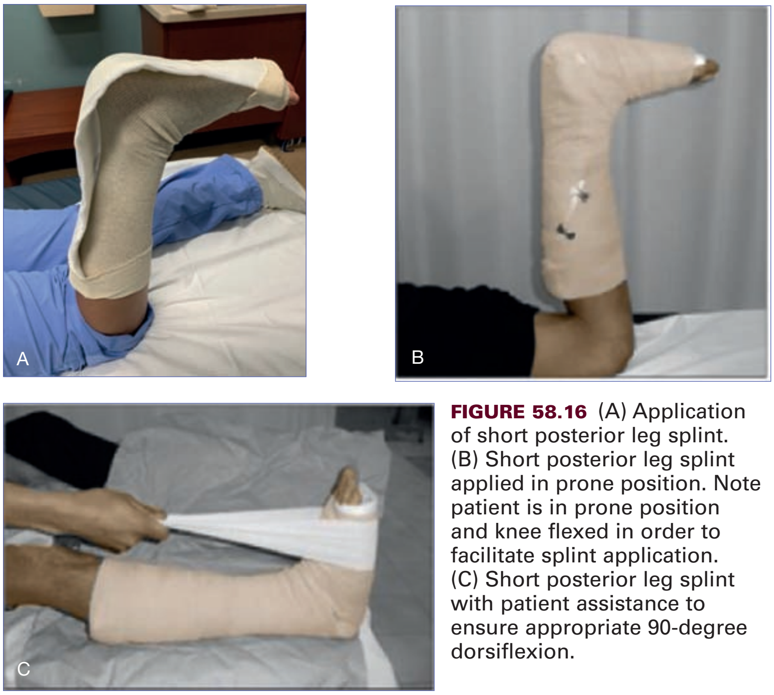


FIGURE 58.16 (A) Application of short posterior leg splint. (B) Short posterior leg splint applied in prone position. Note patient is in prone position and knee flexed in order to facilitate splint application. (C) Short posterior leg splint with patient assistance to ensure appropriate 90-degree dorsiflexion.

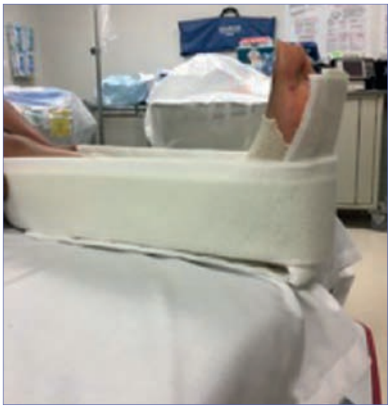
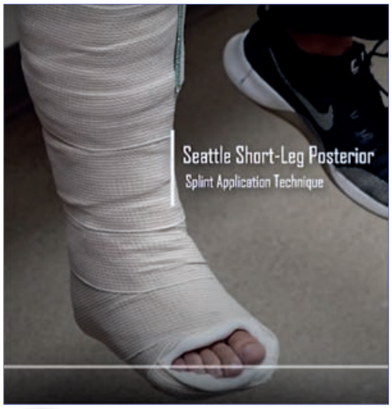


FIGURE 58.17 Combination of short posterior splint and ankle stirrup splint for added stability.



VIDEO 58.8 Short posterior leg splint application.

Source: Proliance Orthopaedics & Sports Medicine. (2019). *Posterior short-leg splint* [Video file]. Retrieved from https://youtu.be/Omd455hgUHY

(*continued*)

TABLE 58.6 Type of Splints (*continued*)

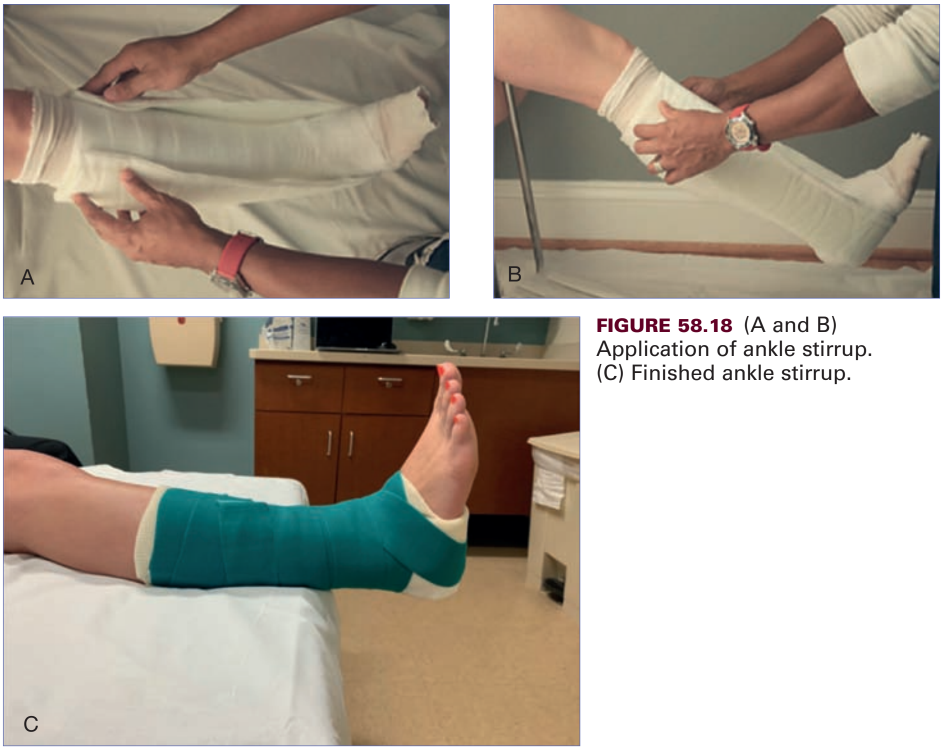
<table>
<tr><th>Type and Indication</th><th>Length</th><th>Width</th><th>Note</th></tr>
<tr><td>Ankle stirrup
(FIGURE 58.18; also see 58.17)
Ankle sprains and minor chip fractures</td><td>From just below the fibular head, running under the heel and to just below the knee on the medial surface</td><td>Half the circumference of the lower extremity</td><td>Should be able to place in a shoe for possible partial weight bearing. Commercially available air casts provide similar lateral stability with improved patient comfort (see FIGURE 58.24).</td></tr>
<tr><td colspan="4">

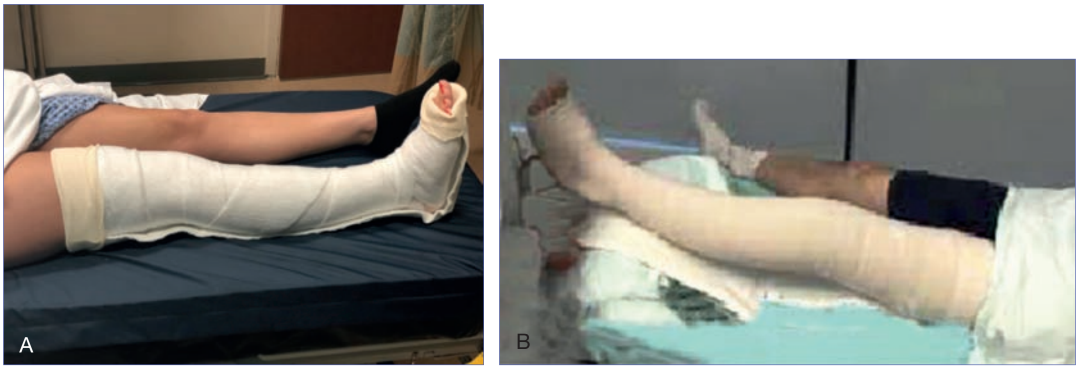
FIGURE 58.18 (A and B) Application of ankle stirrup. (C) Finished ankle stirrup.</td></tr>
<tr><td>Long posterior leg
(FIGURE 58.19 and VIDEO 58.9)
Knee fractures</td><td>Posteriorly just below the buttock crease to 3 cm above the heel</td><td>Half the circumference of the leg</td><td></td></tr>
<tr><td colspan="4">

FIGURE 58.19 (A) Application of long posterior leg splint. (B) Long posterior leg splint.</td></tr>
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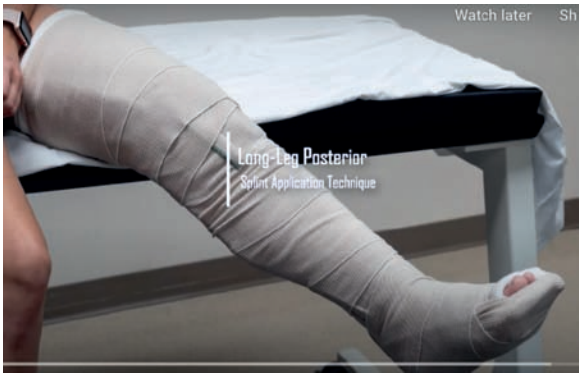
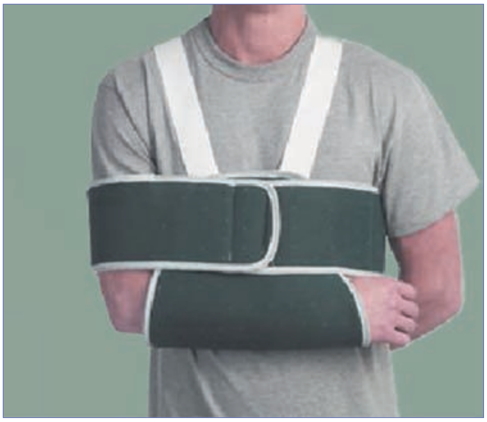
(*continued*)

TABLE 58.6 Type of Splints (*continued*)

Type and Indication	Length	Width	Note
 Watch later Sh Long-Leg Posterior Splint Application Technique **VIDEO 58.9** Long posterior leg splint application. *Source*: Proliance Orthopaedics & Sports Medicine. (2019). *Posterior long-leg splint* [Video file]. Retrieved from https://youtu.be/7yfv26_ldq8			

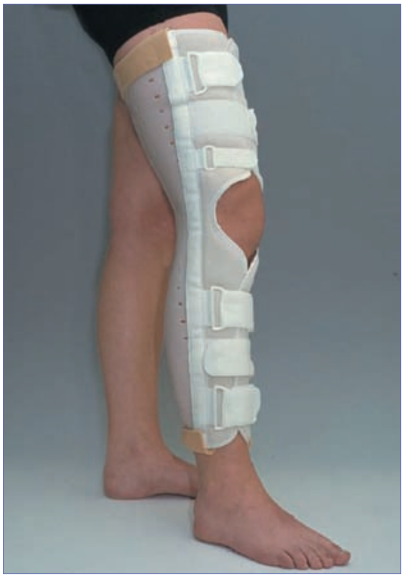
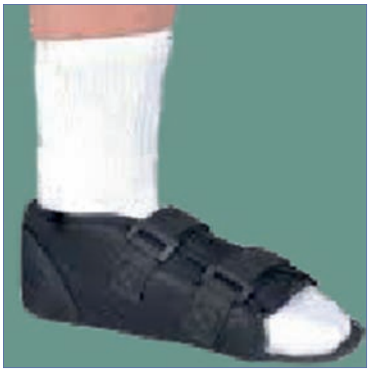
Miscellaneous Immobilization Devices (TABLE 58.7)

TABLE 58.7 Commercially Manufactured Immobilization Devices

Miscellaneous Immobilization Devices	Indication	Length	Notes
Shoulder immobilizer (FIGURE 58.20)	Proximal humerus fractures, dislocated glenohumeral joints, and sprains of the shoulder	NA	Sling supports the weight of the arm, whereas the swathe immobilizes the arm against the chest wall to maximally minimize shoulder movement.
 **FIGURE 58.20** Shoulder immobilizer.			
Knee immobilizer (FIGURE 58.21)	Ligamentous injuries to the knee and arthropathies	Posteriorly just below the buttock crease to 3 cm above the heel	Knee should be in almost full extension. Immobilizer is easily removable, comfortable, and can go directly over clothing.

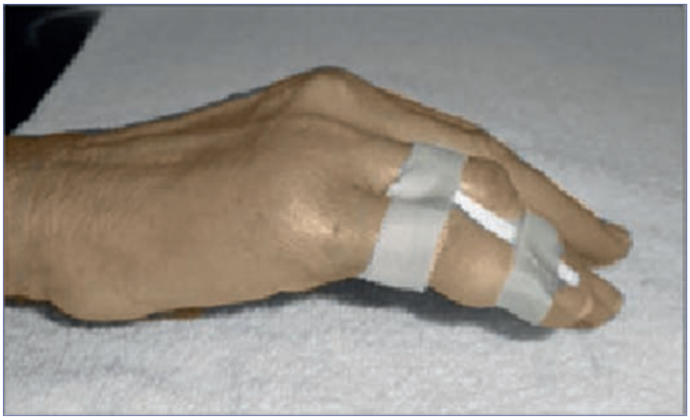
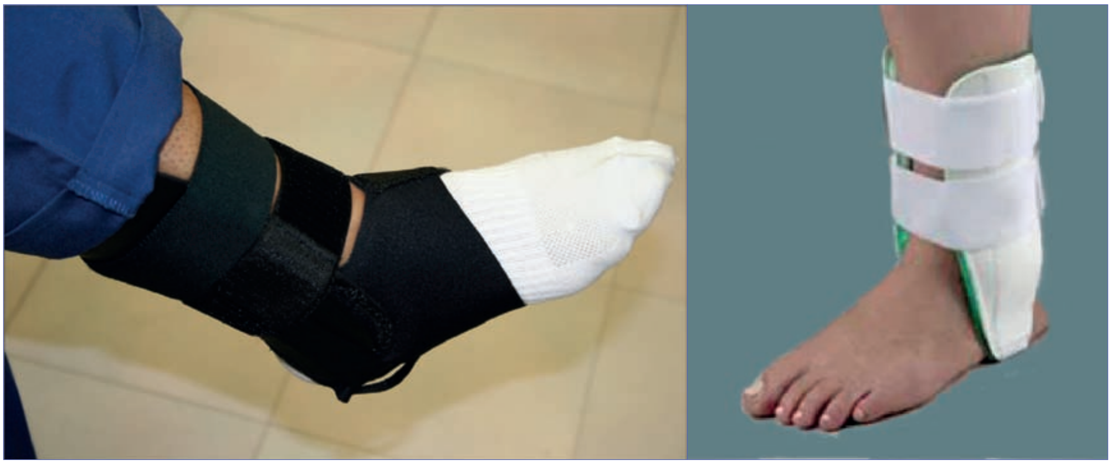
(*continued*)

TABLE 58.7 Commercially Manufactured Immobilization Devices (*continued*)

Miscellaneous Immobilization Devices	Indication	Length	Notes
	 **FIGURE 58.21** Knee immobilizer.		
Postop shoe (**FIGURE 58.22**)	Toe fractures/injuries and minor foot injuries	NA	Usually combined with buddy taping of toe fractures. Can be used over a splint for partial weight bearing.
	 **FIGURE 58.22** Postop shoe.		
Buddy taping (**FIGURE 58.23**)	Finger and toe sprains, dislocations after reduction, and arthropathies. Used in uncomplicated toe fractures; may be used in certain other digital fractures though literature is lacking.	NA	Entails taping injured digit to uninjured adjacent digit which acts as a splint. Use gauze between digits to prevent maceration and/or pressure ulcers. Monitor for skin necrosis and range of motion.

(*continued*)

TABLE 58.7 Commercially Manufactured Immobilization Devices (*continued*)

<table>
<tr><th>Miscellaneous Immobilization Devices</th><th>Indication</th><th>Length</th><th>Notes</th></tr>
<tr><td colspan="2"></td><td colspan="2">FIGURE 58.23 Buddy tape using adjacent finger as a splint. Note gauze between the fingers, placed in an effort to avoid pressure necrosis of the skin.</td></tr>
<tr><td>Ankle air-cast splint (FIGURE 58.24)</td><td>Ankle sprains and minor chip fractures</td><td>NA</td><td>Should be able to place in a shoe for possible partial weight bearing. These commercially available air casts as opposed to ankle stirrup (see FIGURE 58.18) provide similar lateral stability with improved patient comfort.</td></tr>
<tr><td colspan="4">
FIGURE 58.24 Ankle air-cast splint.</td></tr>
</table>

POSTPROCEDURE CONSIDERATIONS

- Postprocedure exam: Always check for intact motor and sensory function, and intact distal extremity perfusion.
- If there has been significant bony manipulation and/or full closed reduction, in some cases postsplint x-rays may be indicated.
- Upon discharge, instruct the patient on proper home care of the splint: Avoid wetting the splint and apply ice packs for no more than 30 minutes at a time.
- If appropriate based on the injury, instruct patients on how to remove the splint and gently clean the area.
- Rest, ice, elevation, and pain control.
- ***Instruct patients to return if pain rapidly increases and/or numbness or parethesia develop.***
- Instruct patients on proper follow-up for definitive management.

COMPLICATIONS

- Ischemia
- Inadequate immobilization
- Nerve palsy
- Muscle atrophy
- Compartment syndrome
- Deep vein thrombosis from prolonged immobilization

PEARLS

- Measure and prepare the splint first.
- Apply the stockinette so that it extends at least 5 centimeters beyond the splint.
- Apply at least two or three layers of rolled cotton padding over the area to be splinted.
- *Be generous and meticulous, avoid wrinkles, and place extra padding around bony prominences.*
- *Place rolled cotton padding between the digits that are going to be splinted to avoid maceration of skin.*
- Wet the splinting material and place it over the area to be splinted.
- Fold the ends of the stockinette over the splint material to smooth the edges.
- For added comfort, place a layer of rolled cotton padding over the splint.
- Apply the elastic wrap around the splint to secure it in place.
- *Wrap the bandage without placing too much tension around the extremity; simply roll it without stretching the material.*
- While still wet, mold the splinting material to conform to the shape of the extremity.
- Place the patient's extremity in the position desired. *Keep the patient still until the splint has dried and hardened (the fiberglass will become warm as it is drying). Fast-drying is dry in 5 to 8 minutes, extra-fast drying in 2 to 4 minutes.*
- After the splint has dried, check the splinted extremity for function, arterial pulse, capillary refill, temperature of skin, and sensation.
- Because occult fractures may be misdiagnosed as contusions or sprains, maintain a low threshold to splint injured extremities: "When in doubt, splint."
- Avoid prolonged periods of splint use of nonfractures to prevent joint stiffness, which can be disabling.
- In the acute extremity injury, swelling will increase over the ensuing 24 hours; do not wrap splints too tightly.
- Consider the diagnosis of compartment syndrome or deep vein thrombosis if a patient reports increasing pain in a splinted extremity.
- Volar splints do not eliminate pronation/supination of the forearm as do sugar-tong splints. They should not be used for the treatment of ulnar or radial fractures.
- When applying the elastic wrap, do so in a rolling manner as opposed to stretching the wrap circumferentially around the splint and extremity.
- Application of lower extremity splints is made easier with the patient in the prone position.
- One must always be cognitive of the notion that in the acute extremity injury, swelling will increase over the ensuing 24 hours.
- When applying a short posterior lower extremity splint, the patient can help keep the ankle at 90-degree dorsiflexion by pulling up on the foot with an elastic wrap (**FIGURE 58.16**).

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UNIT XV

Procedures for Managing Common Gastrointestinal and Genitourinary Conditions

CHAPTER 59

Procedures for Managing Thrombosed Hemorrhoids

Kelly Holz and Zachary Repanshek

BACKGROUND

Hemorrhoids are a fairly common medical complaint, accounting for over one million annual physician visits in the United States, and affecting three out of four people at some point in life. Although symptoms of hemorrhoids may be relatively benign, such as painless bleeding during defecation or anal pruritus, the population presenting to the ED for management often has more severe disease, usually with complaints of extreme pain. This presentation may be indicative of thrombosed hemorrhoids, for which acute management (<72 hours) can result in prompt relief and prevent further sequelae such as permanent skin tags.

Hemorrhoids (pathologic name) arise from the hemorrhoidal plexus (normal anatomical structure), which is composed of submucosal, fibromuscular, arteriovenous sinusoids, and as such are neither arteries nor veins as they lack smooth muscle in their sinusoidal walls. This cluster of sinusoids resembles penile erectile tissue in that it acts as a spongy capillary network. This plexus serves as vascular cushions (called *anal cushions*; **FIGURE 59.1**) that are part of the normal anorectum and aids in defecation in regard to stool control and, in a minor way, in closure pressure, all the while protecting the internal and external sphincter muscles. Hemorrhoids are characterized based on their origin relative to the dentate line (**FIGURE 59.2**).

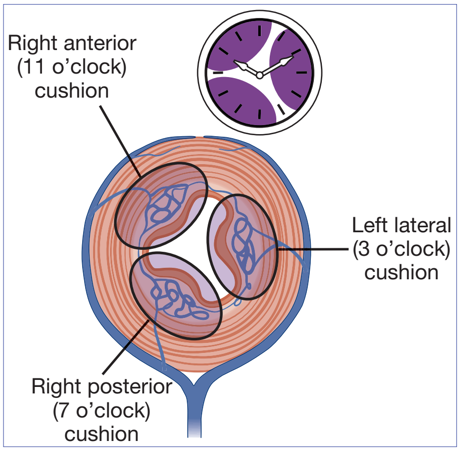

Right anterior (11 o'clock) cushion
Left lateral (3 o'clock) cushion
Right posterior (7 o'clock) cushion

FIGURE 59.1 See consistent area of normal anal cushions. Only upon pathologic growth do these submucosal sinusoidal anal cushions become hemorrhoids.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

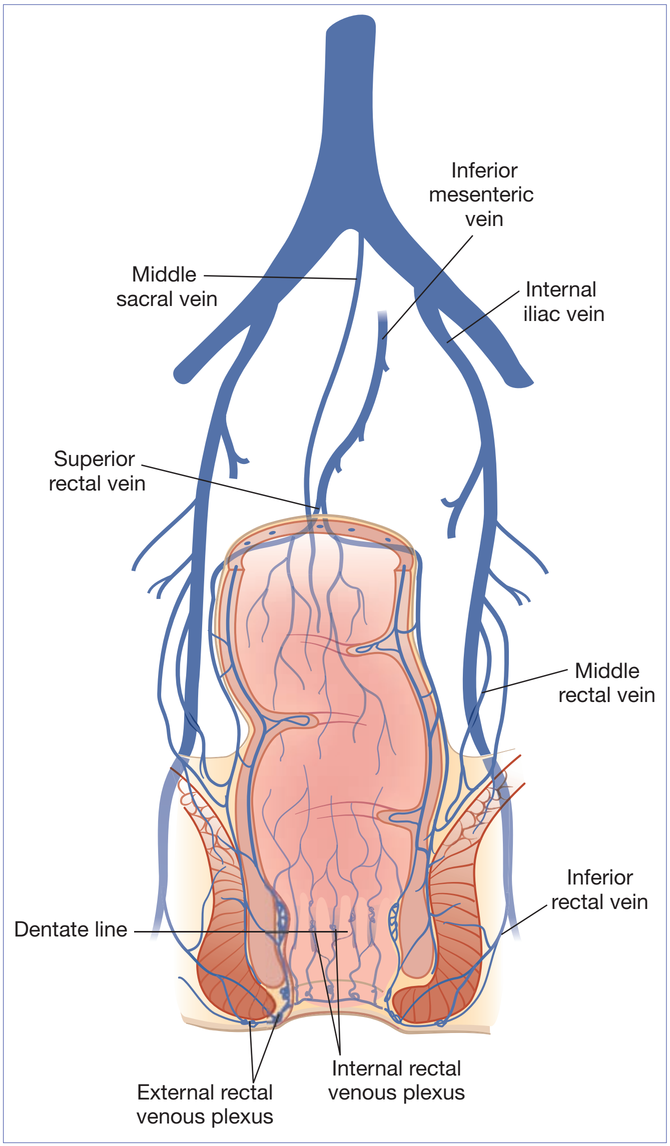

Inferior mesenteric vein
Middle sacral vein
Internal iliac vein
Superior rectal vein
Middle rectal vein
Inferior rectal vein
Dentate line
External rectal venous plexus
Internal rectal venous plexus

FIGURE 59.2 Hemorrhoid anatomy. Only when the normal rectal venous (hemorrhoidal) plexus becomes pathologically enlarged does a hemorrhoid exist.

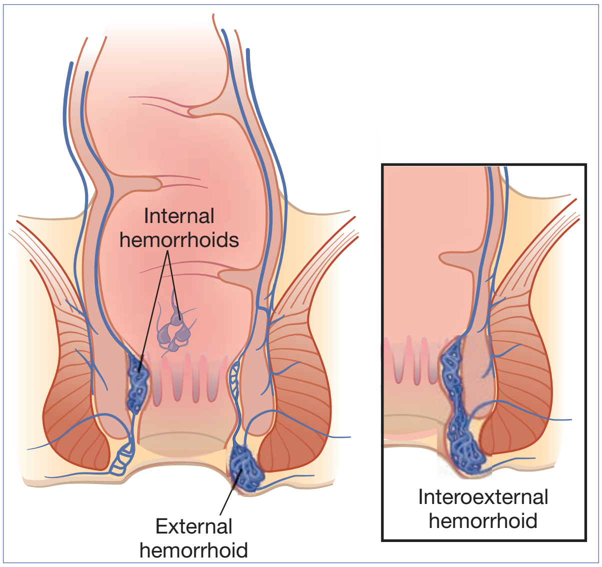

Internal hemorrhoids
External hemorrhoid
Interoexternal hemorrhoid

FIGURE 59.3 Note that there is communication between these two venous systems, which form a plexus-like pattern; interoexternal hemorrhoids may ensue.

- Internal hemorrhoids (**FIGURE 59.3**)
  - Superior to the dentate line
    - Mucosa appearance
  - Viscerally innervated
    - Lack sensation
  - Originate from the superior/middle rectal arteries and drain into the superior/middle rectal veins, which eventually drain into the inferior mesentery vein (portal venous system); some probably does drain into the systemic venous system
- External hemorrhoids (**FIGURE 59.3**)
  - Inferior to the dentate line
    - Note skin appearance (if not thrombosed)

  - Somatic innervation
    - Makes them more sensitive to pain and irritation
      - Often incapacitating when acutely thrombosed
    - Pain is often incapacitating and secondary to engorgement of the plexus from a pooling of blood that acutely swells and eventually clots, creating an acutely thrombosed external hemorrhoid, a bluish-purplish discoloration
  - Originate from the inferior rectal veins that drain eventually into the inferior vena cava (IVC; systemic circulation)

As mentioned, internal hemorrhoids form three cushion-like protrusions at the left lateral, right posterior, and right anterior position (3, 7, and 11 o'clock). These normal anatomic protrusions may aid in the defecation process. External hemorrhoids result from a pathologic growth of these anal cushions as they form a ring-like pattern that slides caudally. The hemorrhoidal plexus is also composed of muscle fibers, subcutaneous tissue, and a generous arterial blood supply, which contributes to the bright-red quality of hemorrhoidal bleeding.

Only when the normal sinusoidal plexus gets enlarged, prolapsed, thrombosed, or symptomatic in any other manner is it referred to clinically as a **hemorrhoid**. Potential causes of symptomatic hemorrhoids include:

- Low-fiber, high-fat diet
- Weakening or loss of surrounding supportive connective tissue from normal aging
- Abnormal bowel functions (diarrhea or constipation)
- Pelvic floor dysfunction
- Any state of increased pressure from altered venous drainage of the anal rectum in the setting of
  - Pregnancy
  - Portal hypertension
  - Conditions of increased straining
- Symptoms are exacerbated by frequent bowel movements, prolonged sitting, and heavy lifting
- Neurologic
  - Paraplegia
  - Multiple sclerosis

Grucela et al. (2010) studied 198 physicians from different specialties and found the rate of correct identification for seven common, benign anal pathologic conditions:

- Anal abscess
- Anal fissure
- Anal fistula
- Prolapsed internal hemorrhoid
- Thrombosed external hemorrhoid
- Condyloma acuminate
- Rectal prolapse

The highest correct diagnoses were that of condyloma acuminate and rectal prolapse, whereas the lowest was for correctly diagnosing hemorrhoidal conditions. There was no correlation between diagnostic accuracy and years of physician experience. The overall diagnostic accuracy among the physicians was 54%, with the accuracy for surgeons being 70% and that for the rest of the doctors being less than 50%.

PATIENT PRESENTATION

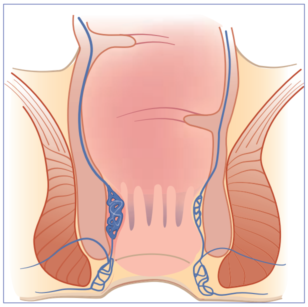
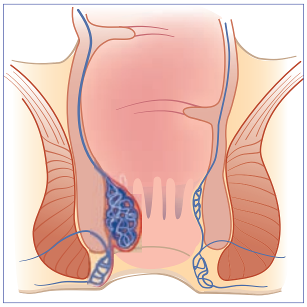
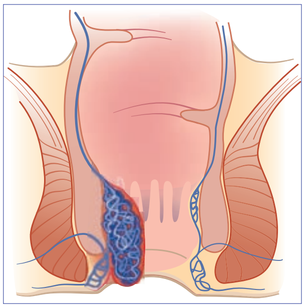
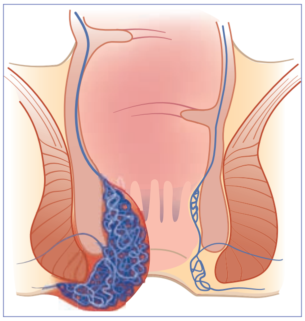
Internal Hemorrhoids

Patients with internal hemorrhoids that have become symptomatic often present with:

- Prolapse of the mucosal tissue (**see FIGURE 59.3**) and/or painless hematochezia, often noted as bright-red blood on the toilet paper or in the toilet bowl
  - Bleeding occurs primarily during defecation of otherwise normal brown stool.
  - Atypical bleeding or melanotic stool should raise suspicion for another cause.
- Pruritus ani
- Mucus discharge
- Intermittent lump, usually postdefecation

Internal hemorrhoids are classified according to the degree of their prolapse (**TABLE 59.1**) and are typically painless. First- to third-degree internal hemorrhoids are treated conservatively with surgical follow-up for definitive treatment, which may include banding, sclerotherapy, or hemorrhoidectomy. Fourth-degree hemorrhoids may be painful as they have a higher risk of becoming strangulated, gangrenous, ulcerated, or thrombosed; any irreducible prolapsed internal hemorrhoids require urgent surgical evaluation and management in order to prevent this potential sequela (**FIGURE 59.4**).

TABLE 59.1 Classification of Internal Hemorrhoids

Type	Prolapse	Reduction	Image
First degree	None	NA	
Second degree	Only with defecation	Spontaneous	
Third degree	Spontaneous	With digital maneuvers	
Fourth degree	Constant	Irreducible*	

*Fourth-degree hemorrhoids warrant a surgical consultation because, if untreated, they will have the sequela of strangulation, thrombosis, or gangrene.

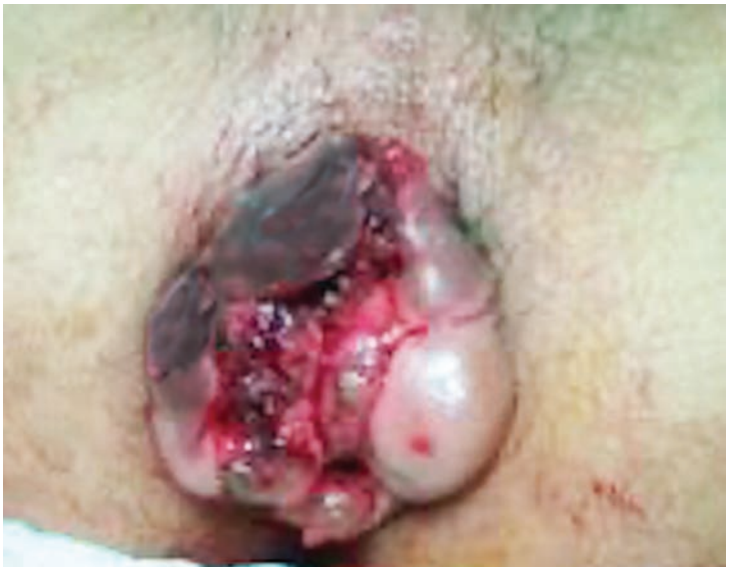


FIGURE 59.4 Fourth-degree internal hemorrhoid with area of gangrene.

External Hemorrhoids

Patients with external hemorrhoids that have become symptomatic often present with anal discomfort or irritation and swelling of soft tissue around the anus (**FIGURE 59.5**), and/or pruritus ani. These symptoms can be managed conservatively using the WASH mnemonic (**TABLE 59.2**).

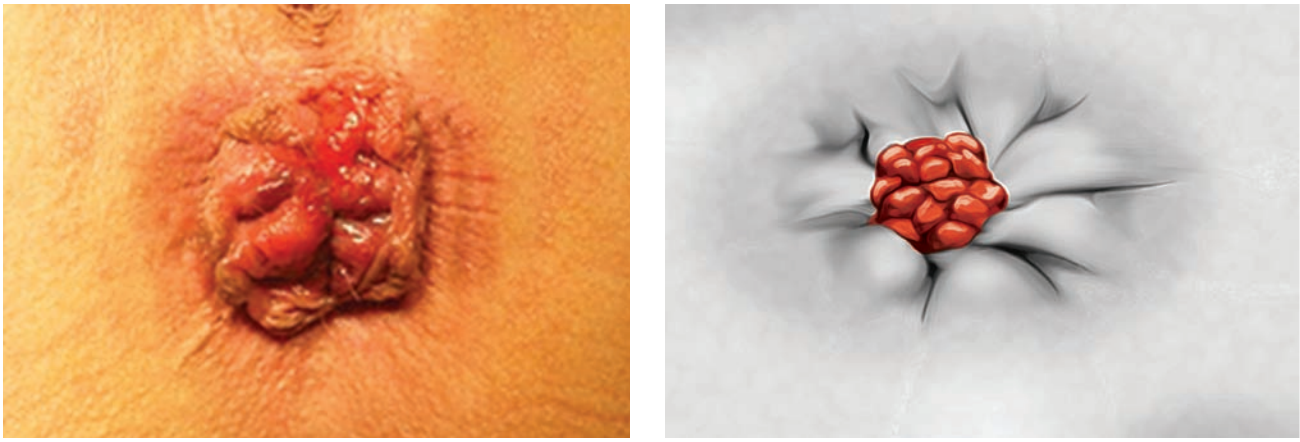


FIGURE 59.5 Photograph and illustration of an internal hemorrhoid, third degree.

TABLE 59.2 WASH Mnemonic

W	Water—increase oral intake, sitz baths
A	Analgesics—Topical anesthetics, steroid creams, witch hazel
S	Stool softeners
H	High-fiber diet

Occasionally, pooled blood in the hemorrhoid will clot and form a painful thrombus. ***Patients presenting with thrombosed external hemorrhoids often complain of extreme pain and/or inability to sit or rest comfortably due to increased pressure, swelling, and inflammation***. Thrombosed hemorrhoids present on visual inspection as exquisitely tender purplish or blue masses in the perianal region (**FIGURE 59.6**).

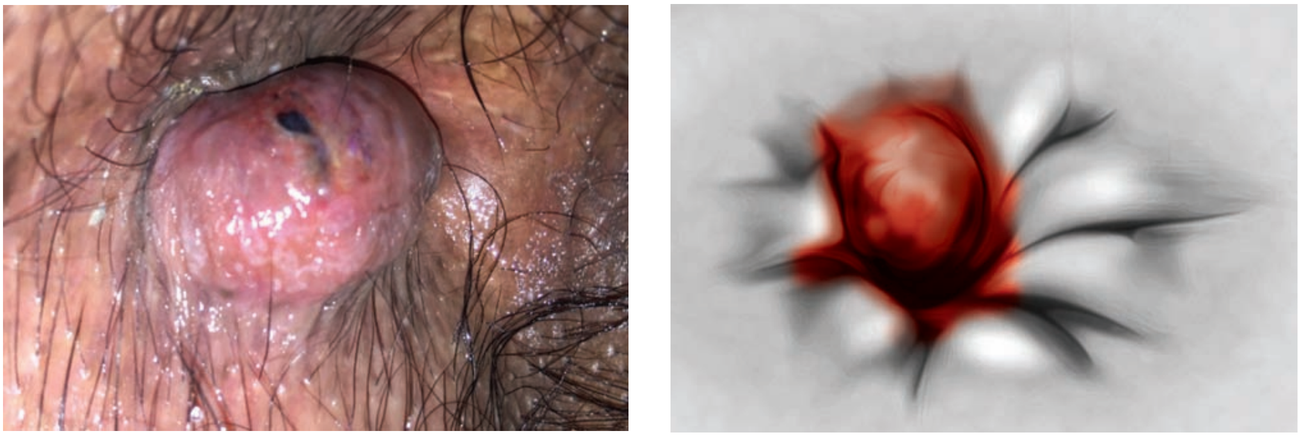


FIGURE 59.6 Photograph and illustration of an external thrombosed hemorrhoid.

TREATMENT

Patients presenting within 72 hours after the onset of pain from a thrombosed external hemorrhoid benefit largely from excision of the hemorrhoid with immediate relief of symptoms. Jongen, Bach, Stübinger, and Bock (2003) retrospectively followed 340 patients who had office-based excision of thrombosed external hemorrhoids and found a recurrence rate of only 6.5% at a mean follow up of 17 months. ***Acute thromboses should be excised—not incised***. Simply incising the tissue leads to incomplete clot evacuation, reaccumulation of clot, and perhaps persistent future perianal skin tags. It is imperative that all clots are removed after excision and unroofing of tissue.

If left untreated, thrombosed external hemorrhoids will generally resolve over a period of a few weeks. Self-limited bleeding may occur if the thrombosis spontaneously erupts, which can be managed with reassurance and the aforementioned conservative measures. There is little indication to excise a thrombosed hemorrhoid after 72 hours, as the body has already started the reabsorption of the thrombus, but this depends on the clinical presentation. The pain relief at this point may not outweigh the discomfort of the procedure itself.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Bleeding disorders
- Anticoagulation
- Immunodeficiency
- Portal hypertension
- Inflammatory bowel disease

PROCEDURE PREPARATION

- The patient should be placed in the knee-to-chest jackknife position (**FIGURE 59.7**) or the left lateral decubitus position.
- Tape the buttocks apart to the side rails of the bed or have an assistant spread the buttocks for better visualization.
- Skin antiseptic solution
- Local anesthetic with epinephrine
- No. 11 blade scalpel
- Forceps
- Hemostats
- Hemostatic sponge
- Gauze pads

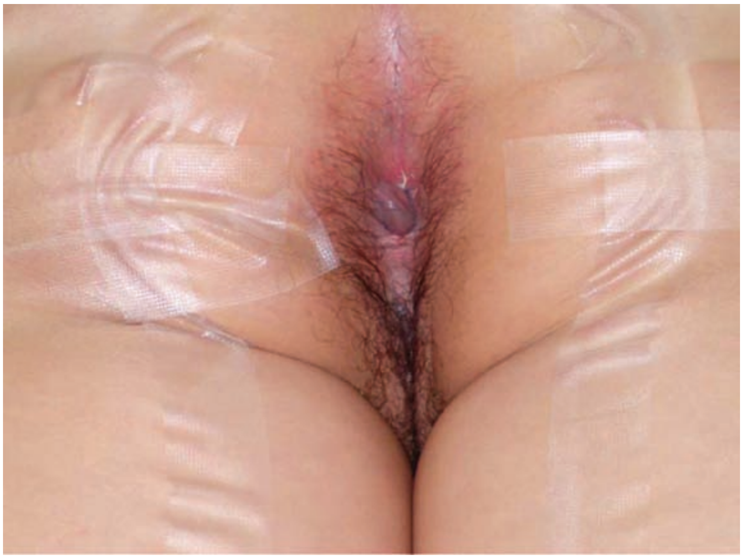
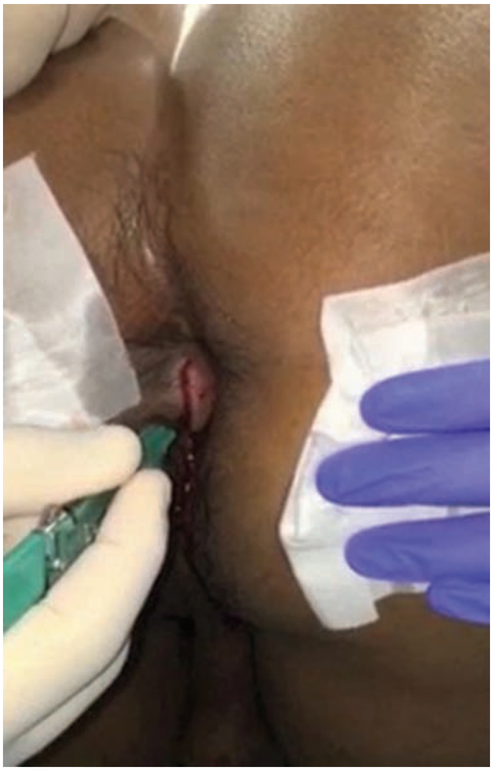


FIGURE 59.7 Taping of patient before procedure.



VIDEO 59.1 Elliptical excision of thrombosed external hemorrhoid.

PROCEDURE

- Skin cleansing technique as described in Chapter 14, Ultrasound-Guided Central Venous Access
- Sterile technique
- Local infiltrated anesthesia is applied with an injection between the skin overlying the thrombosed hemorrhoid and the hemorrhoidal wall, inducing blanching of the entire hemorrhoid.
- An elliptical excision is made in a radial manner, extending from an area just distal to the anal verge outward; never excise toward the anus (**VIDEO 59.1**).
- Unroof the elliptical excision.
- Meticulously remove all clots with manual pressure and curved hemostats (**FIGURE 59.8**).
- Use a 4×4 via curved hemostat to completely probe the unroofed hemorrhoidal plexus for remaining clots; repeat as necessary.
- Place a piece of hemostatic sponge in the wound and cover with a gauze pad.

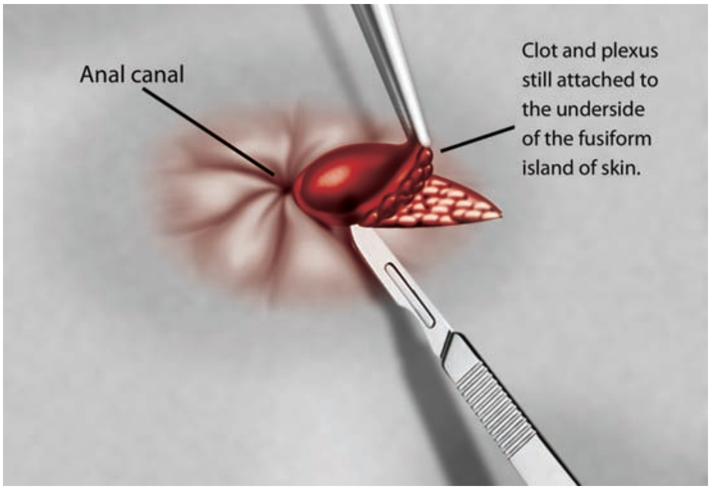

Anal canal
Clot and plexus still attached to the underside of the fusiform island of skin.

FIGURE 59.8 Elliptical excision with clot removed.

POSTPROCEDURE CONSIDERATIONS

- Sponge packing usually spontaneously dislodges within 24 to 36 hours.
- Patients should be advised to begin a high-fiber diet to prevent reoccurrence of the hemorrhoids.
- Encourage sitz baths and the use of stool softeners.

EDUCATIONAL POINTS

- Thrombosed hemorrhoids less than 72 hours old should be excised.
- Thrombosed hemorrhoids greater than 72 hours old can be treated with conservative management or topical calcium channel blocker (0.3% topical nifedipine).

COMPLICATIONS

- Bleeding, infection, and perianal skin tags are potential complications.
- Improper technique may lead to accidental incision of the external anal sphincter, potentially resulting in bowel incontinence. Ensure the excision is always proximal to distal, away from the anus to prevent this rare complication. Never excise toward the anus.

PEARLS

- Patients receive almost immediate relief from excision of thrombosed external hemorrhoids in the first 72 hours after the onset of pain.
- Do not incise external hemorrhoids; always excise them.
- The prone knee-to-chest jackknife position with buttocks taped to side rails provides the best perianal exposure.
- Always excise away from the anus to prevent accidental incision of the external anal sphincter.
- Fourth-degree internal hemorrhoids require surgical evaluation and management.
- Even when hemorrhoids are visualized, it is prudent to consider more serious gastrointestinal disorders as the source of bleeding; always think cancer as well as other serious causes upon physical examination.
- Hemorrhoids cannot be felt unless thrombosed or fibrosed; a painless perirectal mass is cancer until proven otherwise.

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CHAPTER
60

Rectal Prolapse

Kelly Holz and Richard Harrigan

BACKGROUND

Rectal prolapse is the passage of any or all of the rectal tissue through the anal opening. Patients may present with any of the three discrete types of rectal prolapse. Complete rectal prolapse, called ***procidentia***, is the protrusion of all three layers of the rectum through the anal opening. It can be identified by the circular folds of the prolapsed tissue (**FIGURE 60.1**), which can protrude up to 15 centimeters externally. Mucosal prolapse is the protrusion of just the mucous membrane of the rectum through the anus and can be identified by the radial folds of the mucosa at the anal verge. The mucosa generally only extends up to 3 to 4 centimeters externally. Incomplete, or occult, prolapse is the internal prolapse of rectal tissue that does not extend externally through the anal opening. Patients often complain of feelings of incomplete defecation. With occult prolapse, patients have tenesmus and pass blood or mucus in association with constipation. Occult prolapse may be difficult to identify in the ED and does not require emergent reduction.

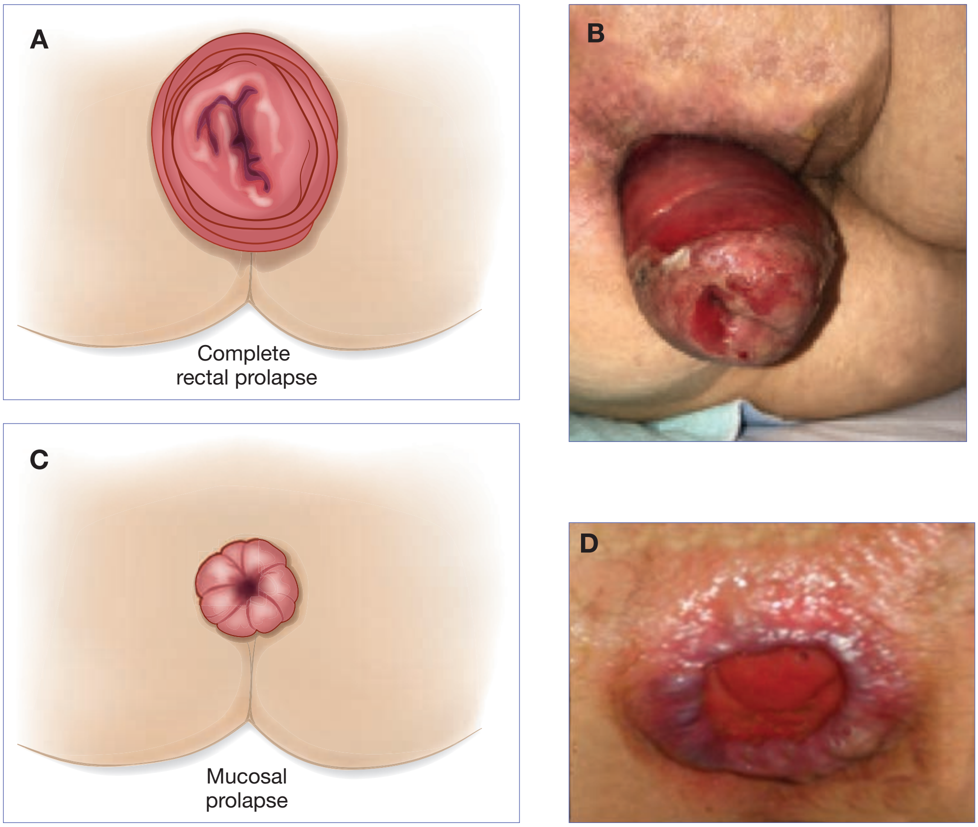

FIGURE 60.1 (A) Illustration and (B) photograph of complete rectal prolapse exhibiting concentric rings. (C) illustration and (D) photograph of mucosal prolapse displaying radial folds.

Source: B, D Reproduced with permission from Medscape.

The rectum is the distal 12 to 15 cm of the large intestine between the sigmoid colon and the anal canal. It serves as a reservoir for fecal material. The dentate line is the junction/separation of the rectum and the anal canal. The internal anal sphincter is made of smooth muscle that is the most distal extension of the inner circular smooth muscle layer of the colon and the rectum. It is 3.25 cm long and normally 2.5-mm thick. The internal sphincter is not under voluntary control and is continuously contracted to prevent incontinence. The external anal sphincter consists of striated muscle that forms a circular tube around the anal canal. Control of the external anal sphincter is voluntary.

Rectal prolapse occurs because of a rectal intussusception typically 7 cm proximal to the anal verge (**FIGURE 60.2**). Constipation and repetitive Valsalvas usually speed this process. Mucosal prolapse occurs when the connective tissue attachments of the rectal mucosa are violated, thus allowing the mucosal tissue to prolapse through the anus; this is often secondary to prolonged hemorrhoidal disease.

As many as 50% of prolapse cases are caused by chronic straining with defecation and constipation. Other risk factors include:

- Pregnancy
- Previous surgery
- Chronic diarrhea
- Benign prostatic hypertrophy
- Chronic obstructive pulmonary disease (COPD)
- Cystic fibrosis
- Pelvic floor dysfunction
- Neurologic disorders

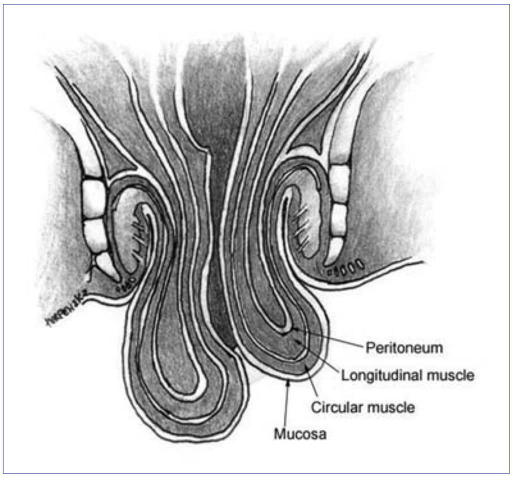

FIGURE 60.2 Rectal prolapse (procidentia), which is an intussusception of the rectum.

Source: Rakinic, J., & Portiz, L. S. (2018). Rectal prolapse. In J. Geibel (Ed.), *Medscape*. Retrieved from https://emedicine.medscape.com/article/2026460-overview#a6. Reproduced with permission from Medscape.

PATIENT PRESENTATION

Patients may present with complaints of a rectal mass/tissue extending out of their anus (**FIGURE 60.3**). Over time, the rectum no longer spontaneously retracts, and patients may have to manually retract it, which will eventually develop into a chronic prolapse. Associated prolapses include:

- Bladder prolapse (17%)
- Cystocele (35%)

Additional or concomitant complaints may include:

- Anal pruritus
- Pain on defecation
- Incontinence
- Rectal bloody/mucoid discharge
- Constipation

Patients may mistake the prolapsed tissue for hemorrhoids. They may describe this as being intermittent. In cases of intermittent prolapse, examination with the clinician's hand over the anal verge during gentle Valsalva as one might normally strain during a bowel movement may precipitate the prolapse and aid in diagnosis.

Rectal prolapse in children typically occurs under the age of 3 and is most often seen as mucosal prolapse. After reduction, children should be sent to their pediatricians for further evaluation of underlying disease processes that may have resulted in rectal prolapse, including but not limited to:

- Chronic diarrhea (IBD)
- Parasitic infection
- Cystic fibrosis
- Malnutrition

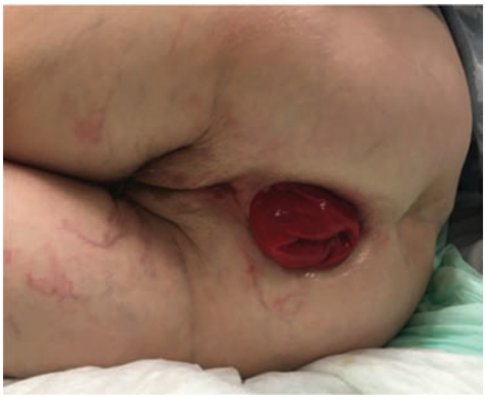

FIGURE 60.3 Presentation of rectal prolapse.

TREATMENT

Patients presenting with rectal prolapse can often be treated with manual reduction; unsuccessful reduction will result in the need for surgery for definitive management.

CONTRAINDICATIONS

Any signs of ischemia or gangrene of the prolapsed tissue warrant emergent surgical evaluation, and manual reduction is contraindicated (**FIGURE 60.4**).

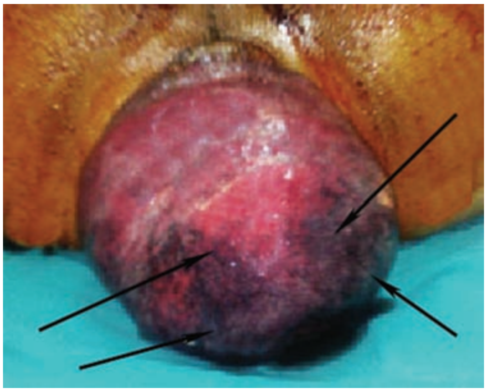

FIGURE 60.4 Rectal prolapse. Note areas of blackened gangrene tissue represented by black arrows.

SPECIAL CONSIDERATIONS

Treatment of rectal prolapse is essentially surgical. All cases should be referred for definitive surgical management.

PROCEDURE PREPARATION

- Equipment:
    - Skin antiseptic solution
    - Sugar, or gauze soaked in sugar water
    - Lubricated gauze
    - Tape
- Place the patient in the prone or lateral decubitus position.
- Procedural sedation is warranted as failure to reduce rectal prolapse is often secondary to an inability to relax the anal sphincter, a problem often resolved with appropriate sedation/perianal anesthetic block.
- Tape the buttocks apart to the side rails to aid in reduction or enlist the assistance of another clinician to hold the buttocks apart.

PROCEDURE

- Cleanse the skin.
- Apply gentle, constant manual pressure to the distal end of the prolapse (the portion closest to the lumen).
- Apply circumferential pressure, with your thumbs at the lumen and your fingers supporting the lateral walls, and gently guide the prolapsed tissue back through the anus.
- If the tissue is too edematous for manual reduction, granulated sugar (sucrose) can be applied to the prolapsed tissue for 15 minutes prior to reduction:
    - The sugar can be sprinkled directly on the tissue, or a gauze pad soaked in sugar water may be applied.
    - The desiccating effect of the sugar has been reported to markedly reduce bowel wall edema in minutes, allowing for successful reduction.
    - Literature is limited to case reports only.
- Lubricated gauze should be taped on to the anal verge and kept in place for several hours following manual reduction.

COMPLICATIONS

- A small amount of bleeding during and after reduction may occur and is not of concern.
- Continuous and/or large-volume bleeding after reduction is a concern, and further imaging and consultation with gastroenterology or general surgery may be required.
- If the prolapsed tissue cannot be reduced or there is any evidence of ischemia, emergent surgical consultation and evaluation are required.
- Delay in the reduction of rectal prolapse can lead to complications, including but not limited to loss of anal sphincter tone leading to long-term fecal incontinence, as well as ulceration, strangulation, and/or perforation of the bowel wall.
- Rectal ulcer occurs in 17% of patients.

PEARLS

- Procedural sedation and/or anxiolytics may be prudent in children and some adult populations.
- Granulated sugar may be used to decrease bowel wall edema.
    - The sugar exerts a mild osmotic power over the prolapsed mucosa, helping the edema to slowly resolve, which permits a nontraumatic reduction and prevents complications (**FIGURE 60.5**).
    - Utilizing this treatment modality can be difference between emergent and elective surgery as it may reduce an incarcerated non-ischemic prolapse; manual reduction may still be needed.
    - The literature is limited to case reports.
- Emergent surgical consultation is warranted if the rectal prolapse cannot be reduced in a timely fashion or if gangrenous or ischemic tissue is present.
- Intermittent rectal prolapse can be discovered on examination by asking the patient to gently perform a Valsalva maneuver while observing the anal verge and supporting it with the examiner's hand: This is useful in distinguishing a prolapsing internal hemorrhoid from a rectal prolapse.
- After reduction of the prolapse, patients should be sent for an outpatient colonoscopy for evaluation of a polyp or malignancy.
- Incarcerated rectal prolapse is rare and manual closed reduction can generally be accomplished.

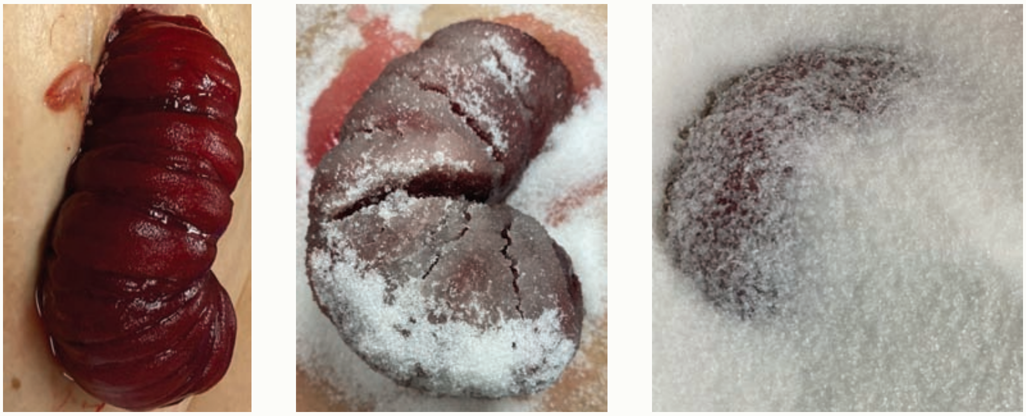

FIGURE 60.5 Granulated sugar placed on a prolapse. Note that sugar can be the difference between emergent and elective surgery. If there are areas of necrosis (black), this technique is contraindicated as the patient would need emergent surgical consultation.

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CHAPTER 61

Procedures for Gastrointestinal Tube Insertion

Caroline Kaigh and Richard Harrigan

BACKGROUND

There are several common indications for gastric intubation, including:

- Gastric decompression after endotracheal tube (ETT) placement
- Treatment of small bowel obstruction (SBO) or ileus
- Treatment of other causes of gastric outlet obstruction
- Gastric bleeding
  - Poor sensitivity and specificity
- Nasogastric feeding/administration of medication

Although placement of a nasogastric tube (NGT) or orogastric (OG) tube to facilitate gastric lavage in the poisoned patient was formerly a common part of clinical practice, in recent years the American Association of Poison Control Centers has recommended against performing gastric lavage secondary to a lack of evidence of efficacy and risk of complications (Gummin et al, 2019). Specifically:

- The amount of toxin removed by gastric lavage is unreliable and negligible, especially if performed after the first hour.
- There are few (if any) situations in which the expected benefits of gastric lavage would exceed the inherent risks, whereas favorable studies are of low quality and/or methodologically flawed; also, the administration of activated charcoal has not been shown to provide equal or greater efficacy of decontamination.
- The literature fails to show evidence suggesting that gastric lavage actually forces toxins into the small bowel.
- Animal and volunteer human studies suggest variable and incomplete return of ingested agents following gastric lavage, even after 15 minutes with rapid decline at 1 hour.
- The literature is limited to case reports that suggest the recovery of ingested tablets with gastric lavage, even in situations in which gastric emptying may be delayed (e.g., hypothermia, anticholinergic syndrome), but there is no evidence that this changes the outcome.
- Finally, in the overdose (OD) patient, complications of placing an OG tube include the following:
  - Incomplete if any decontamination
  - Pulmonary aspiration
  - Hypoxia
  - Laryngospasm
  - Distraction of staff from resuscitation and supportive care priorities

Similar to its use in the OD patient, gastric intubation is theoretically helpful in differentiating upper from lower gastrointestinal (GI) bleeding, but again studies have failed to show benefits from this practice, and it is no longer routinely performed:

- Has not been shown to change the management
- Most upper GI bleeds are from the duodenum

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- Adamopoulos et al. (2003) have shown that the false negative rate is 27% with the sensitivities similar to clinical judgment.
- Kessel et al. (2016) looked at the ability of an NGT to differentiate between an upper and lower GI bleed in patients presenting with melena and found:
  - Of patients, 72% had negative nasogastric aspirate.
  - Sensitivity of the NGT to establish the upper GI as the source of bleeding was only 28%.
  - The negative predictive value (NPV) of a negative NGT aspirate was less than 1%.
  - Most patients who initially presented with melena and were found to have upper GI bleeding via endoscopy had a negative NGT aspirate.
  - Insertion of an NGT does not affect the clinical decision to perform upper endoscopy.
- Rockey, Melo, and Ahn (2014) have shown that in patients presenting with an upper GI bleed, there were no statistically significant differences between groups in regard to the need for endoscopic treatment, rebleeding, mortality, nor the identification of patients with a lesion requiring urgent endoscopic treatment.
  - Also, 35% experienced pain, nosebleed, or NGT placement failure.

The emergency clinician may also be called upon to troubleshoot indwelling surgical feeding tubes, including gastrostomy tubes (G-tubes), jejunostomy tubes (J-tubes), and combined gastrostomy–jejunostomy tubes (GJ-tubes). Patients with long-term G, J, or GJ-tubes may present with a range of complications, including obstruction, dislodgement, or broken tubes. It is important for the emergency clinician to have familiarity with these different types of feeding tubes and the procedures necessary for addressing their complications.

Anatomy

The nostrils are short, obliquely angulated, paired structures separated by the septum. The nasal septum continues to divide the bilateral nasal cavities, which are actually on a horizontal axis parallel to the floor until they transition to the nasopharynx just above the soft palate (**FIGURE 61.1**). Besides the nasopharynx, the 12- to 14-cm pharynx is further delineated into the oropharynx (begins at the end of the soft palate) and the laryngopharynx, which ends at the beginning of the esophagus at the upper esophageal sphincter. The esophagus is a muscular tube connecting the throat pharynx with the stomach and is approximately 20 cm. Just before entering the stomach, the esophagus passes through the diaphragm at the lower esophageal sphincter. Note that during swallowing, the epiglottis bends backward, folding over the entrance to the trachea and preventing food from going into it.

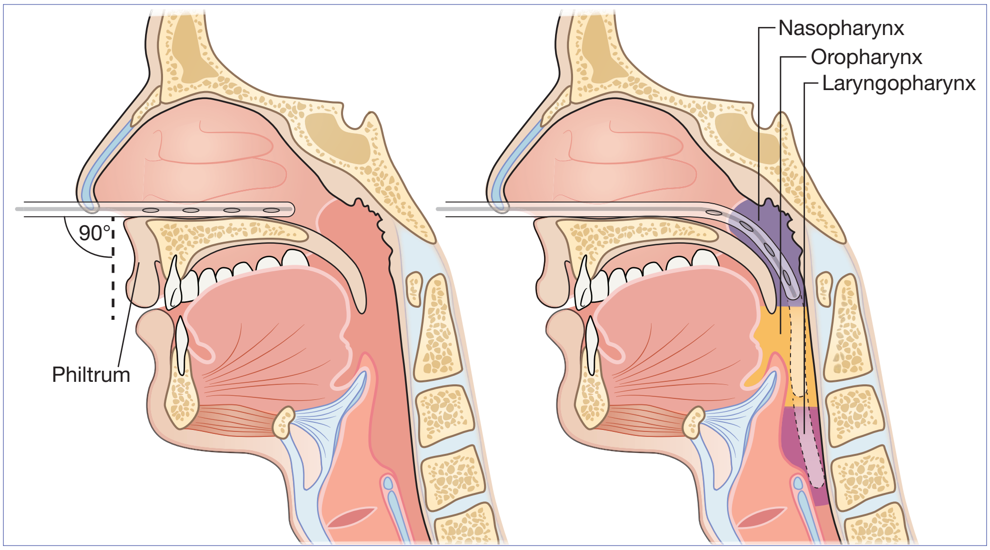


FIGURE 61.1 Anatomy of nasogastric tube passage. Note proximity to epiglottis, vocal cords, and trachea.

NASOGASTRIC AND OROGASTRIC INTUBATION

PATIENT PRESENTATION

Placement of a nasogastric (NG) or OG tube is useful both for the patient with small bowel obstruction or ileus who presents with vomiting, and for the intubated patient requiring gastric decompression.

TREATMENT

Gastric decompression reduces the risk of aspiration, decreases intraabdominal pressure, and increases venous return to the heart. Decompressing the stomach is particularly important in patients who have received prehospital resuscitation without endotracheal intubation, because bag-valve mask ventilation frequently causes excessive gastric distention and this increases the likelihood of vomiting. In endotracheally intubated patients who are sedated and vomiting, including hematemesis, NG/OG tube placement is particularly important for preventing aspiration and subsequent complications.

Gastric decompression is also considered a routine part of the initial treatment of SBO that is associated with significant vomiting and distention, although small studies have failed to prove definitive benefit to decompression in terms of faster resolution of symptoms or decreased rates of complications (see the Complications section). A nonoperative trial of as many as 3 days is warranted for partial or simple obstruction without signs of strangulation or peritonitis and, combined with proper fluid resuscitation, NG suctioning leads to decompression and allows the administration of water-soluble oral contrast, which is further therapeutic in patients undergoing nonoperative management (majority). Resolution of obstruction occurs in virtually all such patients as the literature has shown that such nonoperative management is successful in 65% to 81% of partial SBO cases without peritonitis and/or strangulation.

In a recent metanalysis, Scotté et al. (2016) looked at data in 10 studies with uncomplicated acute adhesive SBO and found no benefit of administering Gastrografin compared with saline solution in reducing the need for surgical intervention (24% vs 20%, respectively) or bowel resection (8% and 4%).

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Known or suspected facial fracture or basilar skull fracture: These can lead to inadvertent intracranial placement of the NG or OG tube
  - Cribriform plate disruption especially as the NGT can end up in the cranium
- Caustic ingestion or severe esophageal stricture
  - Increased risk of perforation
- Known esophageal varices: This can theoretically precipitate severe or life-threatening variceal bleeding, although there is data suggesting this is not a practical risk
  - The notion that enteric tubes (ETs) potentially pose an increased risk of esophageal varices (EV) bleeds is theoretical and anecdotal.
  - Al-Obaid et al. (2019) reviewed NGT placement in 75 patients with known esophageal varices and reported a 2.7% risk of significant hemoglobin drop (<2 g/dL).
- Known esophageal stricture: This can predispose to esophageal rupture.
- Known bleeding risk, bleeding diathesis, or derangement of coagulation factors: This can result in local trauma that can lead to severe bleeding.

SPECIAL CONSIDERATIONS

OG tubes may be somewhat safer than NG tubes in patients with facial trauma or nonvariceal bleeding risk.

- In trauma patients with suspected cervical spine injury, cervical spine immobilization should be maintained during placement of NG/OG tube; this may lead to more challenging placement.
- A variety of sizes of NG/OG tubes are available. In general, 14- to 16-French tubes are effective for gastric decompression. Smaller tubes are more likely to get clogged, especially in the case of SBO when gastric/intestinal contents are to be decompressed rather than air.

PROCEDURE PREPARATION

- Assemble the necessary equipment (**FIGURE 61.2**).
- In the awake patient, pain control can significantly improve the likelihood of first-pass success; options include nebulized or atomized lidocaine, lidocaine gel placed in the naris (before NGT insertion), and water-based lubricant placed on the end of the NG/OG tube.
- Predicting length:
  - Correct placement of the NG/OG tube requires the tip of the tube to be in the stomach (beyond the gastroesophageal junction but proximal to the gastric pylorus). Common mistakes include placing the NG/OG tube with the tip too proximal (in the esophagus) or too distal (in the small intestine).
  - Although the most common method used for predicting appropriate length of NG/OG tube is to measure from the tip of the nose, to the tip of the ear, to the tip of the xiphoid process, this technique often results in an improper position.
    - Fan et al., in an observational study, compared various measuring techniques and found that the most accurate for estimating the internal length was using the distance from the tip of the nose to the earlobe to the xiphoid process plus 10 centimeters; note 27% of the entire study participants had improper NGT position based upon x ray imaging.
    - Using the tip of the nose to behind the ear to the xiphoid process approximates this formula (**FIGURE 61.3**).
  - In pediatric patients, a better estimation of length may be obtained by measuring from the tip of the nose, to the earlobe, to the xiphoid, to the midline umbilicus.

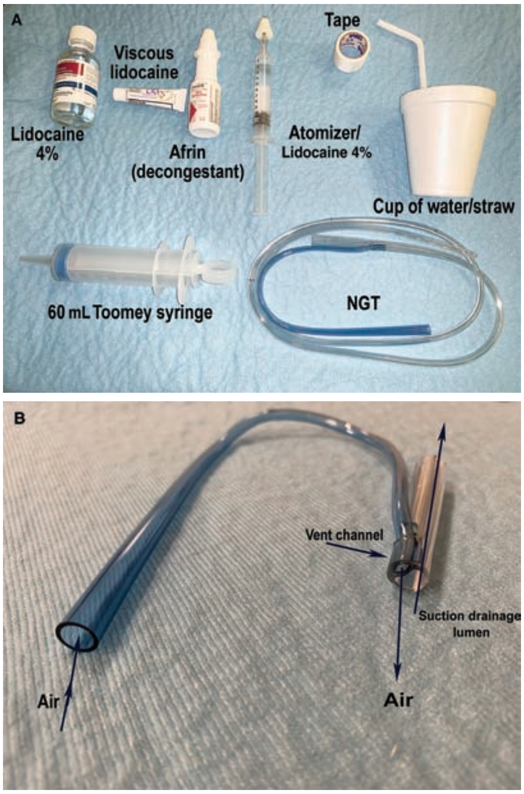


FIGURE 61.2 (A) Equipment needed for a NGT placement. (B) Note the NGT actually has two lumens, one of which acts as a vent lumen that connects distally with the main suction drainage lumen in order to prevent excess suction on the lining of the stomach. Shown in this figure is a cut NGT.

NGT, nasogastric tube.

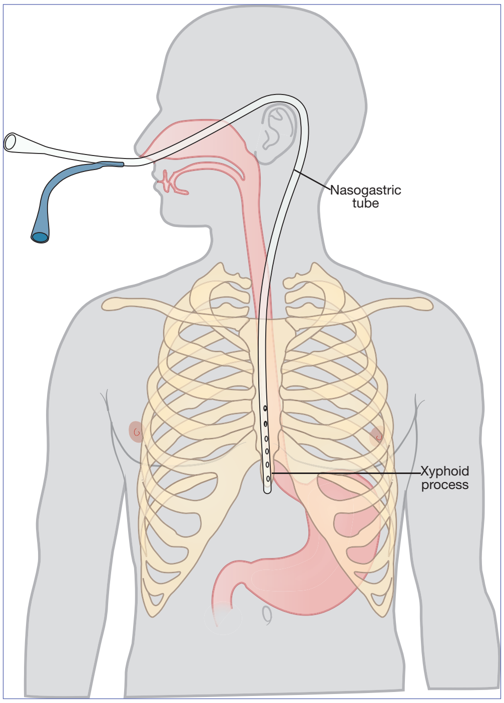


FIGURE 61.3 Before placement of the NGT, get an approximation of the internal depth by measuring from the tip of the nose around the ear to the xiphoid process. This length can also be estimated by measuring from the tip of the nose to the earlobe to 10 centimeters distal to the xiphoid process.

NGT, nasogastric tube.

PROCEDURE

NGT Placement

- In awake patients, sit the patient up if possible.
- Administer appropriate pain control, as indicated previously.
- If possible, flex the neck and direct the chin toward the chest.
  - Flexing the neck narrows the trachea and widens the esophagus (**FIGURE 61.4**).
- Apply a topical anesthetic and perhaps a topical vasoconstrictor.
  - This is a painful procedure.
  - In a meta-analysis of 734 patients, Lor et al. (2018) showed that the application of lidocaine agents prior to the passage of the NGT decreased pain by 26%.
  - In their meta-analysis, Kuo et al. (2010) showed five randomized controlled trials (RCTs) composed of 212 patients in which pretreatment with nebulized lidocaine decreased pain by 58%.
    - Prior to insertion, 4 mL of 10% lidocaine can be nebulized.
- Insert the tube into the most patent naris.
  - Visualize and have the patient simply sniff from each nostril.
- Direct the NGT posteriorly and medially along the floor of the nose and downward into the posterior pharynx.
  - This is a gentle procedure, best done by "feeling" your way along the floor of the nasal passage, rather than forcibly plunging the NGT inward.
  - Many attempt to place the NGT tip vertically; however, the nasopharynx is actually horizontal and parallels the floor; upward placement actually puts the tip against the nasal bridge (**FIGURE 61.5** and **VIDEO 61.1**).
- If you meet resistance, try the other naris.

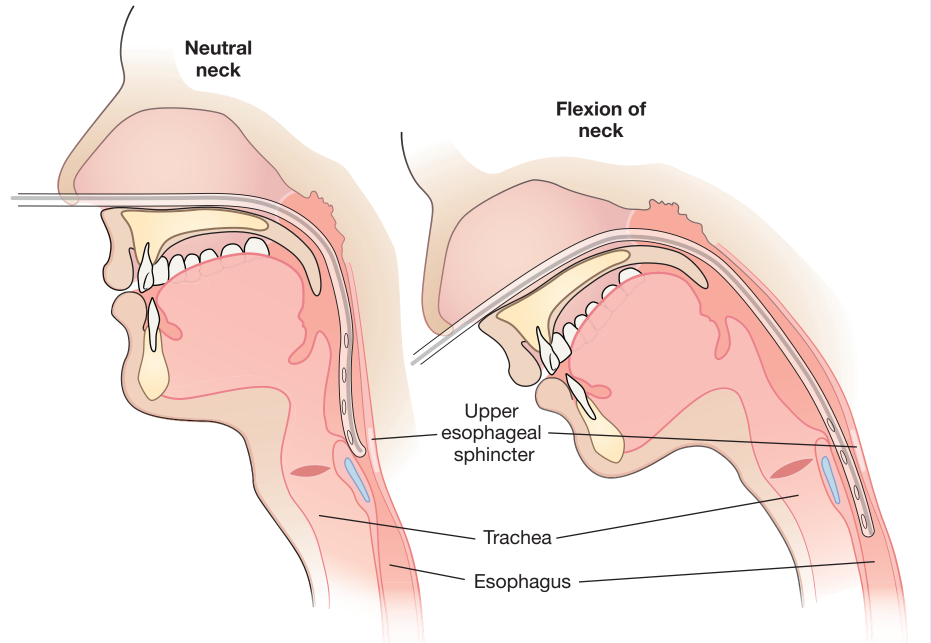


FIGURE 61.4 Graphic display illustrating the benefit of neck flexion in regard to maximizing the passage of the NGT in the esophagus relative to the trachea. Note the highlighted areas show the widening of the esophagus and narrowing of the trachea upon neck flexion.

NGT, nasogastric tube.

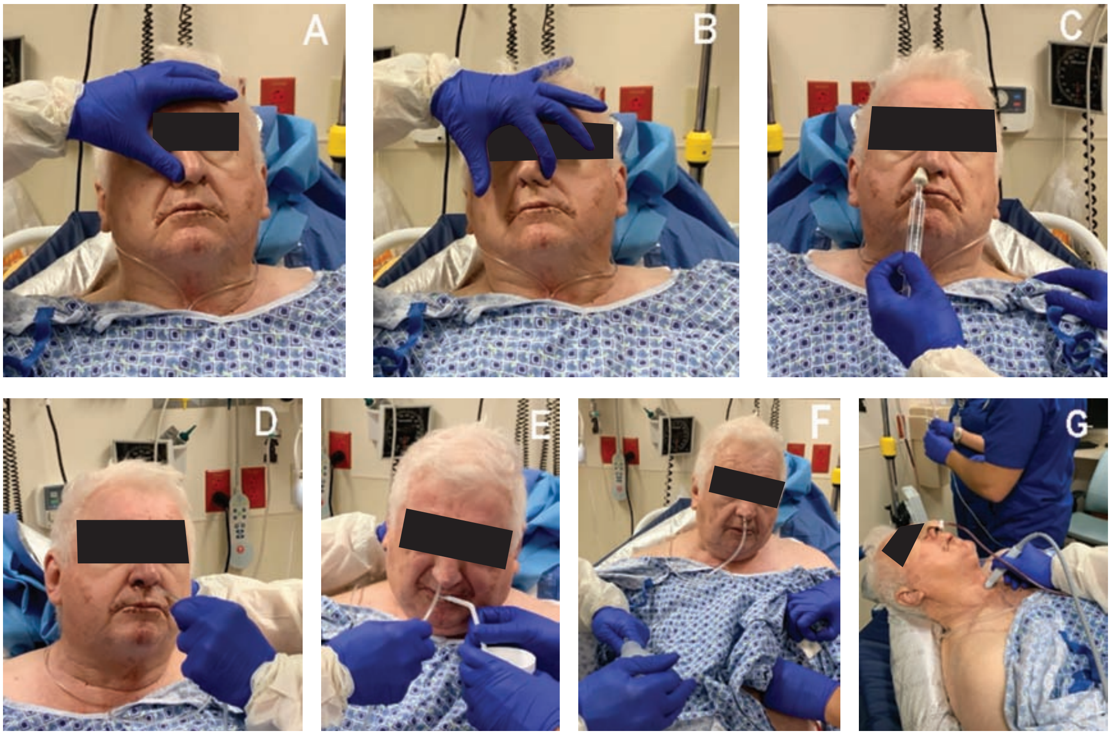


FIGURE 61.5 Steps for NGT placement. (A and B) Assess for the most patent naris. (C) Atomizer coating the nasal mucosa with anesthetic and vasoconstrictor. (D) Insert the NGT along the floor of the mouth parallel to the floor; note the nasopharynx is horizontal, so avoid upward insertion. (E) After insertion past the nasopharynx at the beginning of the oropharynx, have the patient sip water from a straw; this activates the swallowing mechanism and hence the epiglottis covers the trachea to allow passage into the esophagus and not the trachea. Also, by flexing the neck, the trachea's diameter is narrowed while that of the esophagus is widened. (F) Check via insulation in the suction port with an assistant holding a stethoscope over the stomach listening for borborygmi. (G) An adjunctive way to check for esophageal misplacement is to use the high-frequency ultrasound probe over the suprasternal notch looking for the NGT in the esophagus left of the trachea as a hyperechoic structure with posterior shadowing.

NGT, nasogastric tube.

- When the tube reaches the posterior pharynx, an awake patient may gag. Ask the patient to swallow to help direct the tube downward, toward the esophagus.
    - At this point, having the patient drink water from a cup and straw induces swallowing, which better aligns the NGT into the esophagus (closes the epiglottis over the trachea).
- If the patient has excessive gagging or coughing, displays condensation on the interior of the tube, or cannot phonate, you should withdraw the tube, as these are signs that the tube may have inadvertently been placed in the trachea instead of the esophagus.

OG Tube Placement

- Recommended for unconscious patients (typically those with an ETT in place) as it stimulates the gag reflex more so than the nasal route.
- An OG tube decreases the risk of epistaxis and sinusitis.
    - Sinus drainage and ventilation of the paranasal sinuses are dependent on the patency of the osteomeatal complex; NGTs can block and thereby impede sinus drainage, causing stasis of secretions and reduced oxygen tension with resultant superimposed infection.

VIDEO 61.1 NGT placement.

NGT, nasogastric tube.

  - Van Zanten et al. (2005) found that in 30% of critical patients in the ICU, initial fever of unknown origin was caused by NGT-induced sinusitis; other studies show similar results although with a smaller percentage of sinusitis.
- If possible, flex the neck and direct the chin toward the chest.
- Insert the tube into the mouth and then direct it inferiorly and posteriorly into the pharynx.
- One may have to temporarily deflate the ETT pilot balloon in order to allow passage.
- If the patient has excessive gagging or coughing, displays condensation on the interior of the tube, or cannot phonate, you should withdraw the tube, as these are signs that the tube may have inadvertently been placed in the trachea instead of the esophagus.

Additional Considerations in the Intubated and Sedated Patient

- The most common problems encountered when placing an NG/OG tube include inability to pass the tube beyond common sites of obstruction (the piriform sinus and arytenoids being most common), coiling of the tube in the mouth or pharynx, and misplacement of the tube into the trachea (**FIGURE 61.6**).
- Placing an NG/OG tube in an endotracheally intubated patient is often more difficult than in the awake and cooperative patient. Additional methods may be used to facilitate passing the NG/OG tube from the posterior pharynx into the esophagus. With the patient supine and the head in a neutral position:
  - A video assisted laryngoscope (VAL) may be used to directly visualize the tube passing into the esophagus.
  - For an NGT, neck flexion and lateral neck pressure (applied on the same side as the naris through which the NGT has been placed) may be effective in helping the NGT to pass the arytenoids, one of the most common sites of obstruction.
  - The reverse Sellick maneuver is performed by lifting the thyroid cartilage and directing the larynx anteriorly, creating more room for the NG/OG tube to pass into the esophagus.
  - The jaw and tongue can be grasped and lifted anteriorly, thereby opening up the posterior pharynx and elevating the arytenoids, creating more room for the NG/OG tube to pass into the esophagus.
  - If necessary, a Magill forceps can be used (along with a laryngoscope) to place the NG/OG tube into the esophagus.
  - Although not supported by published literature, additional methods of troubleshooting difficult OG tube placements have been described, such as using an endotracheal tube as an introducer (intentionally placing the endotracheal tube into the esophagus, then feeding the NGT through the ET tube).
  - Temporarily deflating the ETT pilot balloon may help pass the NGT into the esophagus.

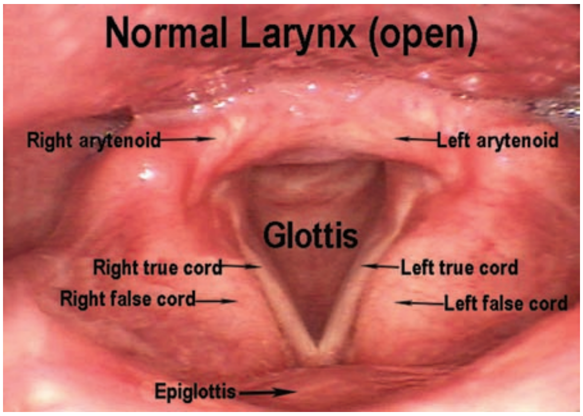


FIGURE 61.6 Areas in the supraglottis where the NGT can meet resistance.

NGT, nasogastric tube.

POSTPROCEDURE CONSIDERATIONS

- NG/OG tubes should be secured after placement to avoid migration. They may be taped to the patient's nose or cheek, but generally should not be taped to an ET tube, in order to avoid dislodgement of both tubes if one should be disturbed; tubes should not be taped too tightly to the nose, as this can lead to pressure ulceration.
- It is necessary to confirm tube placement in the stomach postprocedurally.
  - The gold standard for confirming tube placement is a chest x-ray (CXR; NGTs have a radiopaque line) demonstrating (**FIGURE 61.7**):
    - NGT is in the midline position and the tip is in the gastric lumen below the level of the diaphragm.
      - Preferably 10 cm distal to the gastroesophageal junction

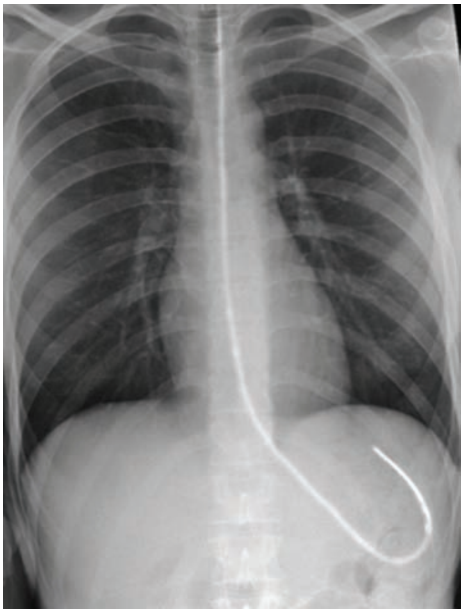


FIGURE 61.7 Proper position of an NGT. Note midline location and the tip at least 10 cm below the diaphragm.

NGT, nasogastric tube.

  - NGT bisects the carina (T4).
    - Shows it is not in the airway
- Ten mL of air may be injected into the tip of the NG/OG tube by a syringe, with a stethoscope over the abdomen; auscultation of borborygmi (gurgling) as the air enters the stomach signals that the tube is in the stomach, although this method is unreliable.
  - Inadvertent bronchial insertion can lead to gurgling perceived in the epigastric area.
  - Metheny et al. (1990) have reported that auscultation has an accuracy of 34.4% for verifying the placement of an NGT.
- Contents may be aspirated from the tube and their pH checked. A pH less than 5.5 is consistent with gastric fluid.
- Qualitative or quantitative capnography may be used to confirm gastrointestinal, rather than tracheobronchial, placement of the NG/OG tube.
- Point-of-care ultrasound (POCUS) is now being evaluated for NGT verification (**FIGURE 61.8**).
  - Vigneau et al. (2005) conducted a double-blind experiment in which a fellow who received brief (approximately 2 hours) training successfully inserted NGTs into 33 ICU patients.
    - This study showed that ultrasonography had 97% sensitivity and could be performed in a shorter time than conventional radiological examinations and the authors suggested that a CXR should be taken in patients in whom tube placement could not be verified using ultrasonography.

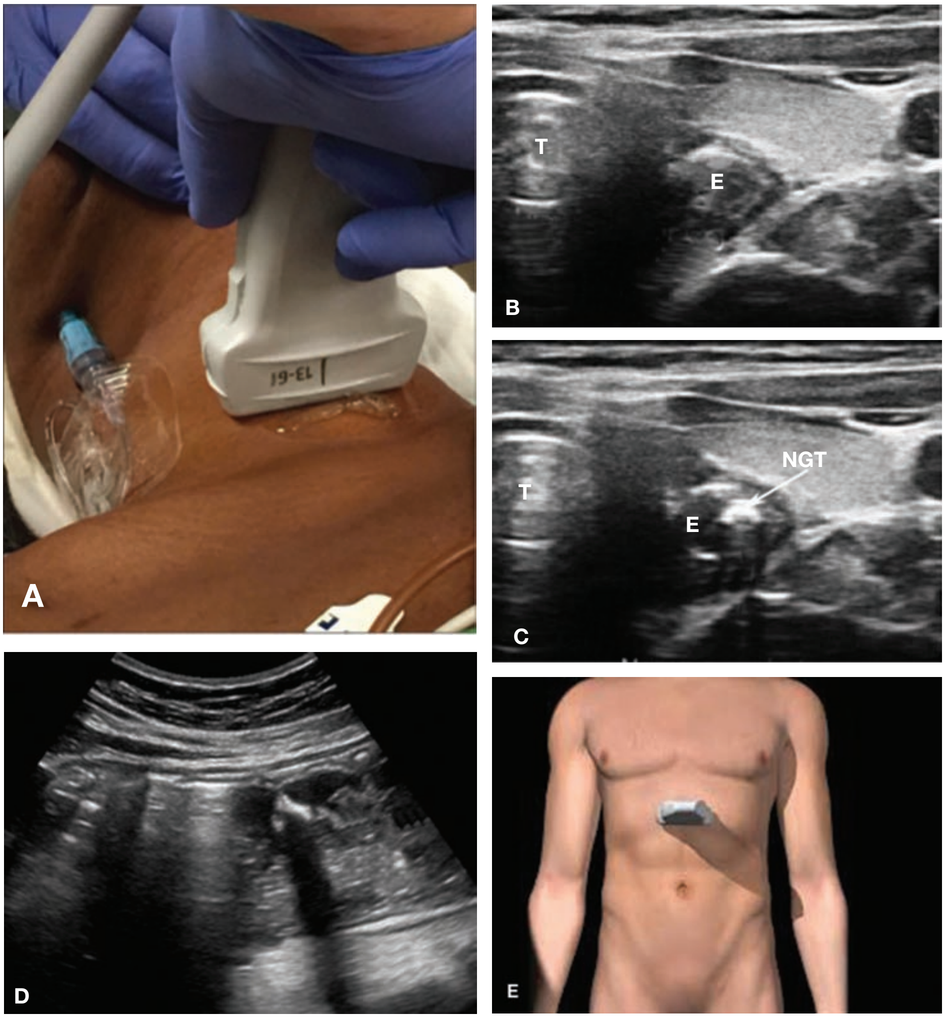


FIGURE 61.8 (A) Transverse view with high-frequency probe just cranial to the suprasternal notch. (B) ETT in place in the trachea with the esophagus (left to the trachea) empty. (C) Same view, now with the NGT in the esophagus as represented by being hyperechoic and possessing posterior shadowing. If the NGT has been passed but the esophagus is empty and hasn't changed, the tube is either in the trachea or coiled in the mouth. (D and E) Curvilinear lower frequency probe in the epigastrium showing the NGT tip with posterior shadowing; this view may be a challenge secondary to body habitus and gas.

ETT, endotracheal tube; NGT, nasogastric tube.

        - Gok et al. (2015) looked at placing an NGT in the ICU in 56 mechanically ventilated patients prospectively using a transverse view just cranial to the suprasternal notch and, after identifying the esophagus to the left of the trachea, placed an NGT and in real time identified its proper placement in the esophagus 93% of the time.
            - For one patient without detection of the NGT in the esophagus, CXR showed it in the trachea.
- In patients for whom the NG/OG tube is placed for gastric decompression, the tube should be connected to suction. Tubes placed for gastric decompression typically have two lumens. The larger clear lumen can be connected to suction, while the smaller blue lumen serves to "vent" the tube, equalizing the gastric pressure with atmospheric pressure to prevent damage to the gastric mucosa caused by the end of the tube being drawn by suction against the gastric wall. Intermittent wall suction is generally safer than continuous suction for preventing damage to gastric mucosa.

COMPLICATIONS

- An NG/OG tube that is not ideally positioned on confirmatory radiography or other means mentioned previously will need to be repositioned.
    - A tube with its tip in the esophagus should be advanced, and a tube with its tip beyond the pylorus should be pulled back.
- A tracheal-placed NGT must be immediately recognized as it can lead to potentially fatal complications from introducing enteral feeds or medications into the lung.
- Minor trauma to the mucosa of the nasopharynx, posterior pharynx, or esophagus can occur from NGT/OGT placement; because of the risk of severe bleeding from minor trauma in patients with coagulopathies, NGT placement should be considered on an individual case-by-case basis in terms of risk/benefit ratio.
    - Optical coherence tomography (OCT) may be a better option in the patient with a coagulopathy.
- Rarely, more serious complications may occur, such as esophageal perforation or intracranial placement of the tube (cribriform plate injury).
    - Because of these risks, NGTs should not be placed in patients with a history of:
        - Esophageal stricture
        - Significant facial trauma
            - OGTs are theoretically safer in patients with facial fractures (bypasses the cribriform plate) as it will not penetrate the cribriform plate; oral passage may be less traumatic, resulting in less bleeding than their nasal counterparts in patients with severe coagulopathy.
- NG/OG tubes that are left in place over longer periods of time can lead to:
    - Damage to gastric mucosa
    - Pressure ulceration of the naris
    - Sinusitis

INDWELLING GASTROINTESTINAL TUBES

PATIENT PRESENTATION

The most common complaint among patients with an indwelling gastrostomy tube (GT; **FIGURE 61.9**), jejunostomy tube (JT), or gastrojejunostomy tube (GJT) is tube dislodgement, which occurs in 2% of patients within the first 10 months after placement; in addition, 37% become dislodged within 5 years. Other issues include tube obstruction, leakage, or breakage.

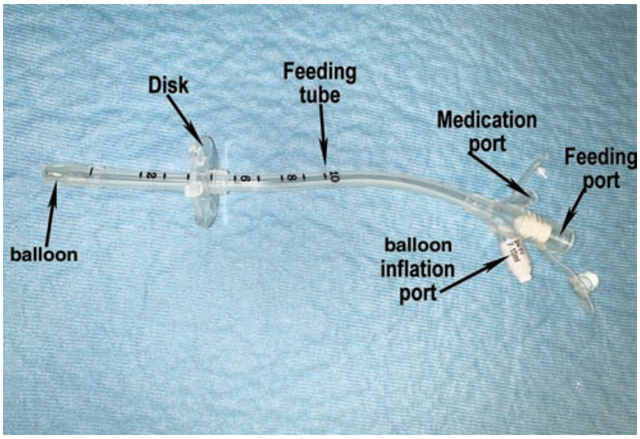


FIGURE 61.9 Anatomy of a GT.
GT, gastrostomy tube.

TREATMENT

In general, patients with indwelling GTs, JTs, or GJTs require them for nutrition, so if they stop functioning, they must be replaced in a relatively acute time period. Tubes that are obstructed or leaking can occasionally be fixed without exchanging the tube, though this is not the norm. For a GT that needs to be exchanged, the appropriate setting for doing so (ED/OR/IR) is largely dependent on the amount of time that has elapsed since the tube was placed and the amount of time that it has been out. Because JTs and GJTs are more complex and involve the small bowel, troubleshooting these tubes is often left to the specialists who placed them. This section concentrates on GT replacement, the standard balloon GT to be specific. Note that a simple gastrostomy track takes approximately 2 weeks to initially begin to form a mature track (gastrocutaneous fistula) but is not well formed until 4–6 weeks; for those patients presenting within this time period with displacement, a replacement should not be attempted.

A GT is actually a secondary device, placed after the primary device is placed via a percutaneous endoscopic gastrostomy (PEG) technique via an endoscope (**FIGURE 61.10**).

Typically, after 8 weeks or so, the PEG primary device can be replaced by a secondary device, typically a standard balloon-tipped GT. However, and for the sake of mentioning them, there are other secondary devices:

- Low-profile gastrostomy tubes (**FIGURE 61.11**)
  - Sits flush against skin wall, balloon tipped, and is easily replaced
  - Types include
    - Balloon
      - MIC-KEY button
      - AMT MiniONE button
    - Nonballoon
      - AMT Non-Balloon MiniONE
      - BARD button

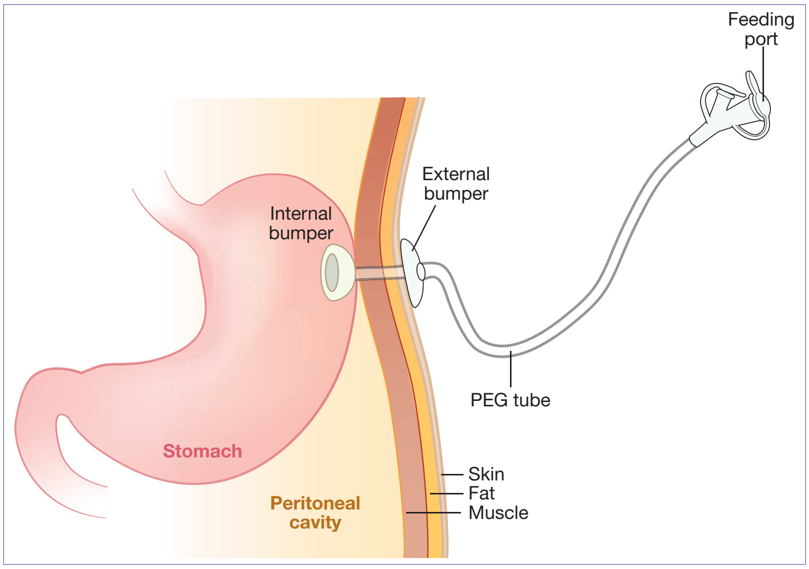


FIGURE 61.10 Primary device percutaneous endoscopic gastrostomy tube. Note that it takes at least 8 weeks for the gastrocutaneous fistula (track) to form.

PEG, percutaneous endoscopic gastrostomy.

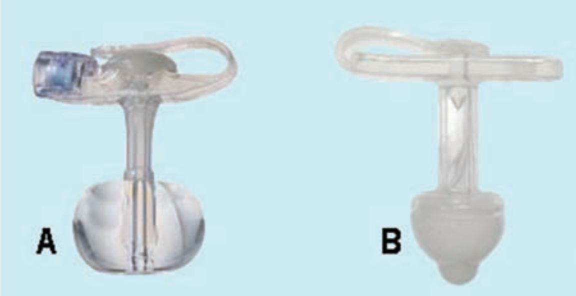


FIGURE 61.11 Low-profile gastrostomy tubes. (A) Balloon (B) Nonballoon.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- It takes 2 to 3 weeks for the tract of a new GT to mature. If a GT was placed less than a month ago, you should consult the clinician who placed it (or the surgeon or interventional radiologist on call at your institution) rather than trying to replace it yourself. An attempt at replacement through an immature tract can lead to inadvertent placement of the tube into the peritoneal cavity, which can lead to peritonitis and sepsis.
    - The stoma of a GT can begin to close after just 2 hours without a tube in place and progresses rapidly in 8 to 24 hours. If a tube has been out for longer than that, consider trying to replace it with a smaller size tube, or consulting surgery or interventional radiology. There is a small amount of evidence from pediatric emergency medicine literature supporting the safety of dilation of the stoma with serial placement of progressively larger Foley catheters. Some clinicians feel comfortable attempting to gently dilate the stoma with a blunt instrument, such as a pair of curved forceps, but there is only a paucity of literature to support the safety or efficacy of this.
        - Bhambani, Phan, Brown, and Thorp (2017), in a pediatric study, noted 32% of patients presenting with GT dislodgment required some form of serial stoma dilation for tube replacement with a complication rate similar to patients without stomal dilation (one patient had a mispositioned and overfilled balloon that was quickly resolved).
        - Authors concluded that given the high frequency of dislodged GTs and the fact that stoma dilation can be performed without an increased complication rate, it seems reasonable that stoma dilation to successfully replace a GT in a pediatric patient should be within the scope of emergency medicine practice.

SPECIAL CONSIDERATIONS

- In patients who are malnourished or immunocompromised, or who have significant ascites, it may take longer for the tract of a G tube to mature.
- Many clinicians will temporarily place a Foley catheter into the tract of a dislodged GT while gathering supplies to replace the GT, or if there is a more critical patient in the department whose care will cause a delay in replacing the G tube.
- Leaking tubes, that is fluid oozing from around the GT, are typically replaced; they can be caused by any of the following:
    - An increase in intraabdominal pressure
        - Constipation
        - Vomiting
        - Coughing/respiratory distress
    - Balloon has deflated
    - Incorrect size, improper stabilization
    - Tube displacement
    - Poor wound healing
    - Inability to decompress stomach
- If a patient has a break in the tube such that a portion of the tube remains inside the patient, you should discuss with surgery whether the patient needs further intervention. Many G tubes that are placed percutaneously (PEG tubes) are made of silicone, which can often safely be eliminated from the GI tract, but can rarely lead to obstruction; if such a patient is to be discharged, you should counsel them to check their stool daily for the GT remnant, and they should have a low threshold to return to the ED for signs of obstruction.
- Another common complaint of patients with indwelling GT is GT obstruction.
    - The first step to unclogging an obstructed tube is to instill a small amount of warm water into it, cap the tube, and wait about 20 minutes.
    - Then, attempt to gently push small amounts of warm water through the tube, and see whether the obstruction has cleared.
- Many patients will attempt to declog tubes at home using either meat tenderizer or carbonated beverages.
    - Although there is no evidence to support the efficacy or safety of this method, instilling a small amount of carbonated beverage into a clogged G tube is unlikely to cause further harm as long as excessive pressure is not used.
- There are several commercially available products to unclog the tube that may be available at your institution.
    - These include enzymes that are reconstituted with water and instilled into the tube, and mechanical devices that are inserted into the tube and twisted to break up an obstruction.
    - These should be used with care, as excessive force can break the device inside the tube and lead to further obstruction and other complications.

PROCEDURE PREPARATION

- Verify what type of tube the patient has by asking the patient, examining the tube, and searching prior records. You should attempt to replace a tube with one that is as similar as possible to the old one. If you are not sure what kind of tube you are dealing with, especially if the old tube is still in place in the patient, you should call the specialist rather than attempting to manipulate an unknown tube yourself.
- Perform an abdominal exam prior to the procedure to look for signs of peritonitis. You should also look for signs of infection around the G tube.
- Replacement of a GT may be somewhat uncomfortable for the patient, but should not be painful.
  - Some clinicians use lidocaine jelly to numb the skin; however, there is no literature to support the safety or efficacy of this.
  - If attempting stomal dilation with either a cotton tip swab or via gentle use of curved hemostats, use a local anesthetic.

PROCEDURE

- Gather all of your supplies: gloves, skin cleanser, new G tube, water or saline to inflate the balloon of the new G tube, syringe to inflate or deflate balloon, lubricant, and tape (**FIGURE 61.12**).
  - Have an extra G tube a size smaller in case of difficult placement.
- Check the balloon of the new tube by filling it with water or saline.
  - The package of the new tube should tell you the volume of the balloon.
  - Deflate the balloon of the new tube before starting the procedure.
- If the old G tube is still in place and needs to be removed, deflate the balloon and gently pull out the tube.
  - Note that some PEG tubes do not have balloons:
    - Mushroom tipped
    - Button tipped
- Clean the skin around the opening of the tract.
- Lubricate the end of the new tube and gently insert it into the stoma. It should advance with only gentle pressure.

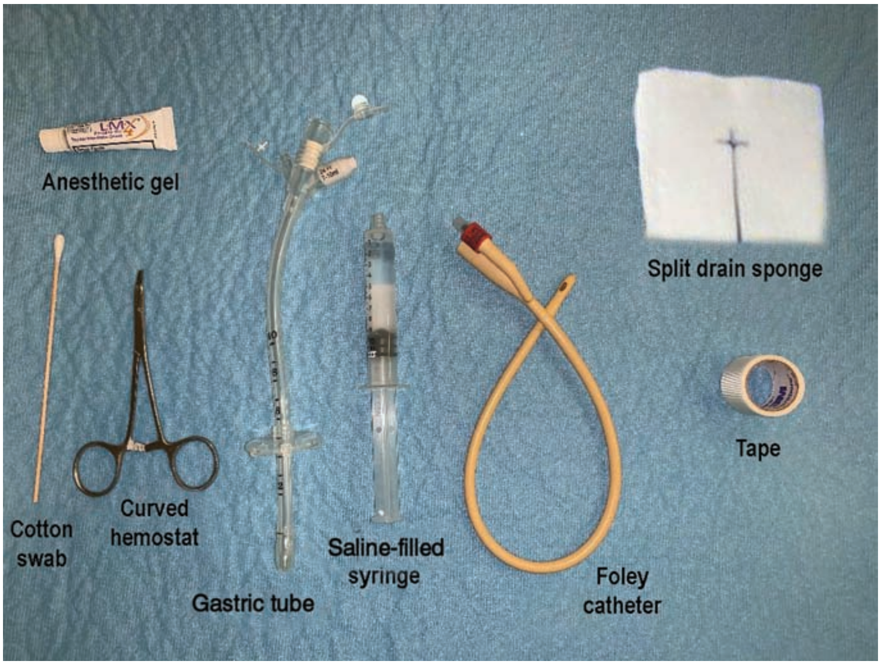


FIGURE 61.12 Equipment needed for GT placement.
GT, gastric tube.

- Insert until the buttress is against the skin, then inflate the balloon and pull back until the balloon bumps up against the wall of the stomach and lower the buttress until snug, which prevents the balloon from migrating and causing a gastric outlet obstruction (**FIGURE 61.13** and **VIDEO 61.2**).

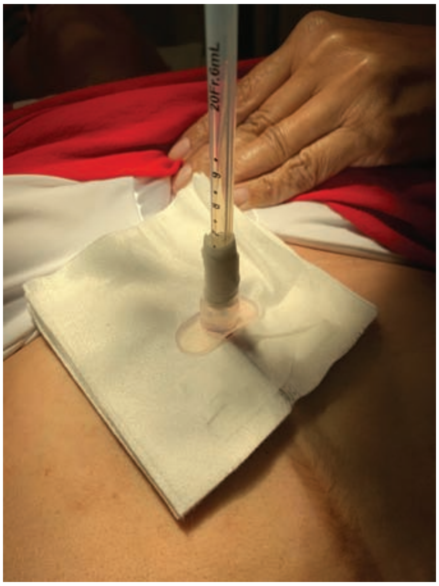
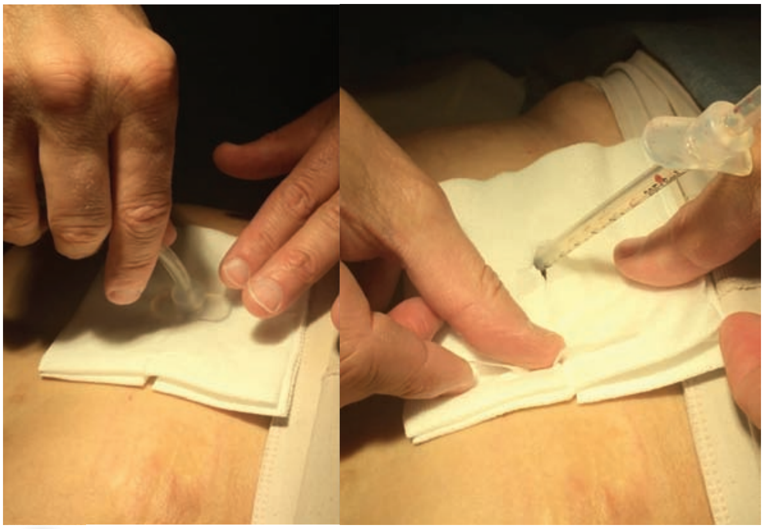


FIGURE 61.13 Gastric tube replacement. Apply tape above the external bumper in order to prevent it from slipping as it may do with time. If this occurs, the end of the tube may slip further into the stomach, which can lead to leaking; if it continues to migrate, blockage of the pylorus may ensue (gastric outlet obstruction).



VIDEO 61.2
Gastric tube replacement. Note that by using a drain sponge and cloth tape, neither the device nor tape comes into contact with the patient's skin.

POSTPROCEDURE CONSIDERATION

- Confirm tube placement by obtaining an abdominal x-ray with approximately 30 mL of Gastrografin injected into the tube (**FIGURE 61.14**). Gentle administration makes spillage and obscuration of the radiographic image due to external contrast material less likely. Consider covering the patient's abdomen around the base of the tube with an absorbent pad in case there is spillage. Visualizing the contrast in the lumen of the stomach and outline of rugae confirms tube placement.
- The importance of checking for the correct position cannot be overemphasized. In **FIGURE 61.15** you can see a rare case in which the G tube was initially placed in the sigmoid colon and, after maturation of the stoma, the G tube was replaced without a contrast check. The patient presented with feeding contents immediately being expelled in bowel movements and a subsequent dislodgement led to a replacement; the resulting contrast check is seen.
- Once you know the tube is correctly placed, lower the buttress to the skin.

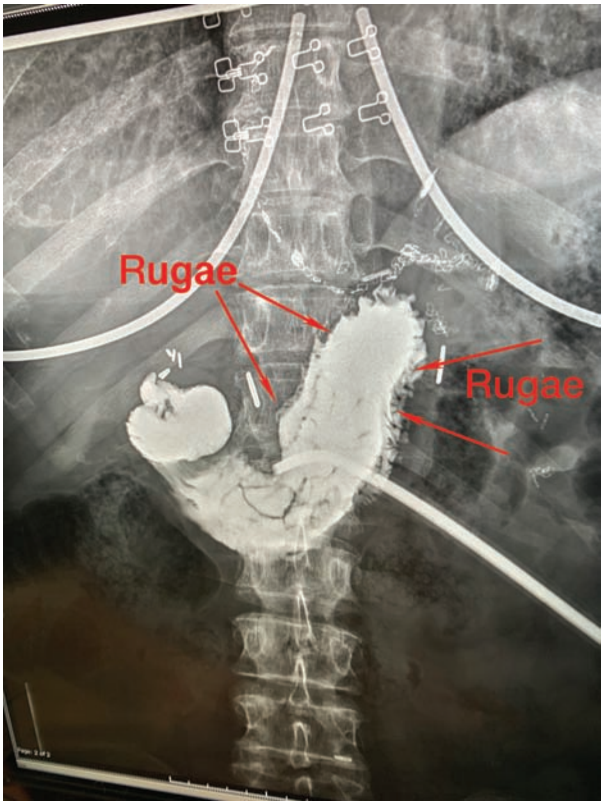


FIGURE 61.14 Proper appearance of abdominal x-ray confirming tube placement.

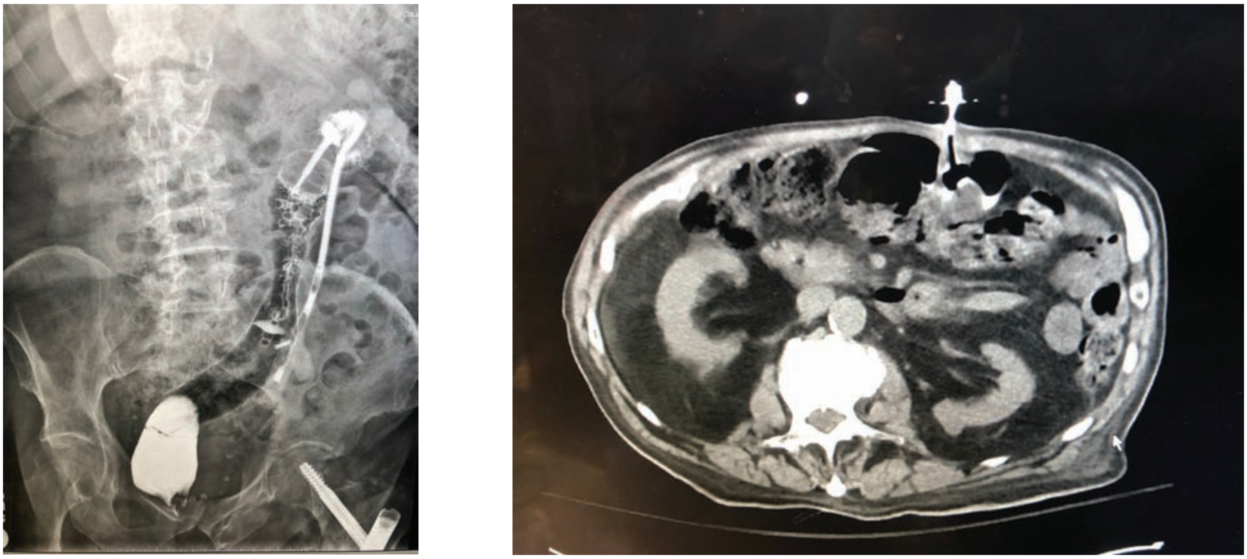
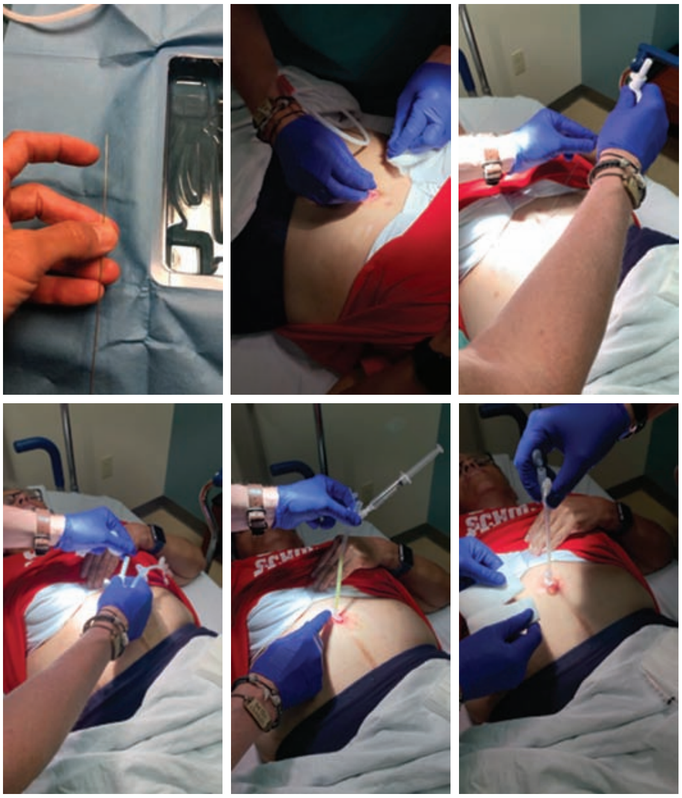


FIGURE 61.15 Contrast check of gastric tube replacement shows the G tube in the sigmoid colon. CT verifies the improper placement.

G tube, gastric tube.



VIDEO 61.3 Seldinger technique using a soft-tip wire for stoma entry and dilation. This is a case presentation and is not recommended for routine use.

COMPLICATIONS

- The most significant complication of G-tube replacement is inadvertent placement of the tube into the peritoneal cavity. This can lead to peritonitis and sepsis. If the postprocedure x-ray shows that the tube is not in the stomach, surgery should be urgently consulted for further guidance.
- If the balloon of the G tube migrates away from the wall of the stomach, it can lead to gastric outlet obstruction. The buttress should therefore be placed flush with the skin to avoid this complication.

Special Circumstance

VIDEO 61.3 highlights using a soft-tip wire in a patient with a prolonged GT dislodgement. Using a Seldinger cricothyrotomy kit and gentle pressure only, the stoma was easily opened. The dilator was placed and then the GT was successfully placed over the wire in a Seldinger manner. Although this is a case presentation, it is not recommended for routine use.

PEARLS

- Preparation is everything; have all of your supplies ready before you start the procedure, and bring an extra tube in case of difficult placement.
- For NGT/OGT placement, neck flexion and other related manipulation can help the tube pass beyond points of obstruction.
- Never tape the NGT to the ETT, as if the former is dislodged, the patient inadvertently loses their airway.
- If you are planning to replace a GT, make sure you are certain of what kind of tube the patient has and the time frame of its placement and dislodgement.
- Always verify the placement of your NGT, OGT, and GT, as the complications of a misplaced tube can be significant.
- Foley catheters placed as temporary replacement feeding tubes are permissible and applauded as it will keep the stoma open, but the patient should be instructed to schedule definitive feeding-tube replacement as soon as possible as they clog easily and the tip may disintegrate in the stomach's acidic environment.
- Smaller GTs clog quicker, so use the largest possible.
- Routine, proactive flushing during feeding and medication administration is the best way to prevent many clogged tubes, yet up to 57% of nurses do not flush before giving medications according to various literature.
- Some type of tube should be inserted to stent a mature stoma, regardless of the type of tube, or the stoma may close within hours and the patient might require a more complicated procedure to regain access.
- Never replace a GT in an immature track.
- It helps to tape the NGT suction adapter to the patient's leg or elsewhere in order for it not to be misplaced after insertion (**FIGURE 61.16**).

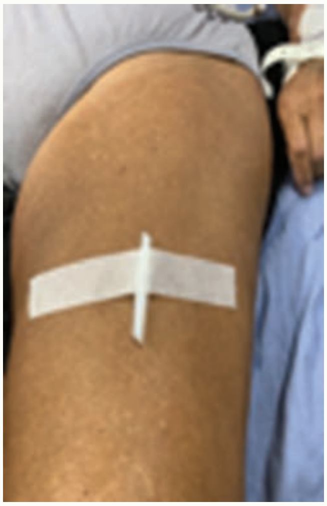


FIGURE 61.16 Photograph showing a nasogastric tube suction adapter taped to patient's leg.

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CHAPTER 62

Procedures for Hernia Reduction

Adria Simon and Richard Harrigan

BACKGROUND

A *hernia* is defined as an abnormal protrusion of an organ or tissue from its normal muscular or fascial cavity through a pathologic opening, usually secondarily to weakening. Abdominal hernias are secondary to a defect in the surrounding supporting abdominal wall allowing intestine and/or intraperitoneal fat to protrude. Weakness is secondary to:

- Aging
  - Loss of tissue elasticity
    - It has been demonstrated that alterations in the collagen component and in the elastic fibers of the extracellular matrix of the transversalis fascia (inguinal hernias) and other fascia occur with aging; these factors favor the development of hernias and their recurrence after surgical repair.
      - In contrast, the etiology of indirect inguinal hernia in children is of congenital origin; they develop from the presence of a vaginal process or of a nonobliterated peritoneum–vaginal duct.
        - ❑ The vaginal process remains open in 15% to 37% of male individuals; however, only a small percentage develops inguinal hernia.
  - Increased intraabdominal pressure
  - Failure of proper healing
    - Incisional hernias can occur in up to 20% of all abdominal wall surgical cases.
  - Abdominal wall trauma

This chapter focuses solely on abdominal wall hernias (**FIGURE 62.1**). After reading the sections that follow, ***one should focus on ensuring the mass/protrusion is:***

- Indeed intestine/intraperitoneal fat and not hernia mimickers:
  - Aneurysm
  - Abscess
  - Lymphoma
  - Lymphadenitis
  - Testicular torsion/tumor
  - Hydrocele
  - Rectus sheath hematoma
  - Diastasis recti
  - Varicocele
- Not of the incarcerated/strangulated types

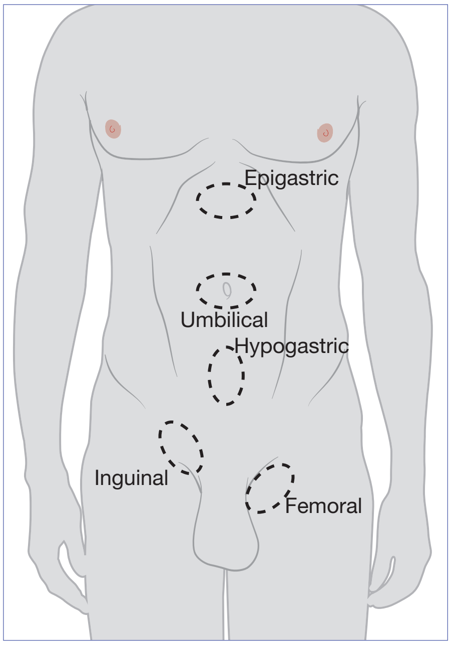


FIGURE 62.1 Common abdominal wall hernia locations.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

Inguinal Hernias

- *Occurs above the inguinal ligament*
  - Sonographic ligament that begins from the anterior superior iliac spine (ASIS) and progresses to the pubic tubercle (**FIGURE 62.2**)
- Bimodal distribution, with peaks around age 5 and after age 70
- Bulge in the inguinal region or scrotum (**FIGURE 62.3**), sometimes intermittent; may be accompanied by a dull ache or burning pain, which often worsens with exercise or Valsalva maneuvers
- Most frequently encountered hernia, representing 75% of all abdominal wall hernias
- 90% in males
- Further defined as
  - Indirect (67%)
    - **Protrude** through the deep inguinal ring lateral to the inferior epigastric artery (**FIGURE 62.4**)
      - Although this classification *may* be determined on physical examination, the clinical distinction between direct and indirect inguinal hernias does not change management in the clinical setting.

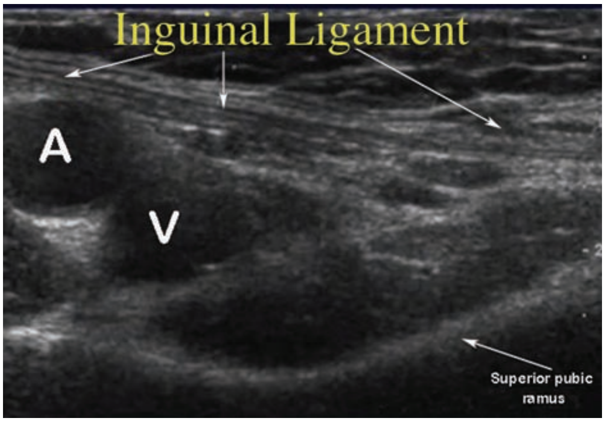

Inguinal Ligament
A
V
Superior pubic ramus

FIGURE 62.2 Note the ligament that inserts from the ASIS to the pubic tubercle.

A, artery; ASIS, anterior superior iliac spine; V, vein.

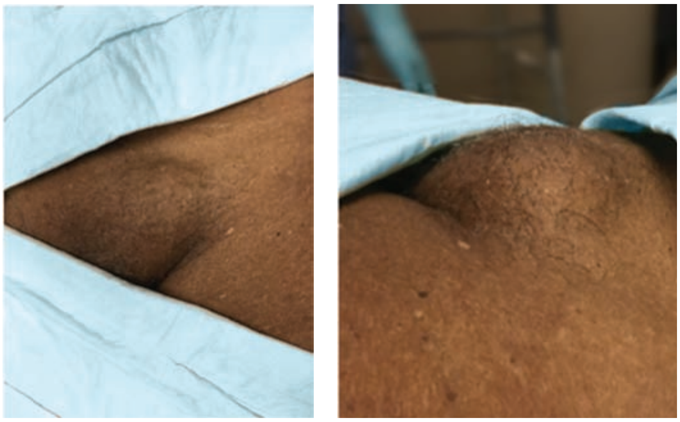


FIGURE 62.3 An incarcerated inguinal hernia pictured from the anterior and lateral views.

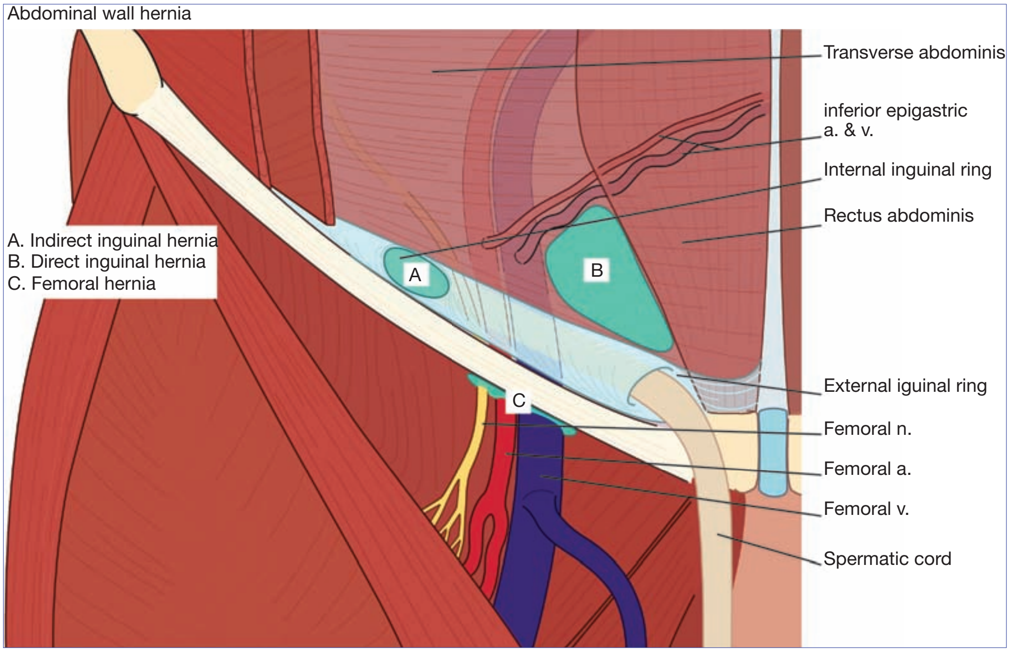

Abdominal wall hernia
A. Indirect inguinal hernia
B. Direct inguinal hernia
C. Femoral hernia
A
B
C
Transverse abdominis
inferior epigastric a. & v.
Internal inguinal ring
Rectus abdominis
External iguinal ring
Femoral n.
Femoral a.
Femoral v.
Spermatic cord

FIGURE 62.4 Abdominal wall hernia anatomy of various types.

a, artery; n, nerve; v, vein.

- Direct (33%)
  - Protrude medial to the internal ring of the inguinal canal and inferior epigastric vessels through Hesselbach's triangle

Ventral Hernias

- Generic term given to any abdominal wall hernia other than the inguinal type.
- Commonly encountered
- Further defined by location as
  - Epigastric (3%; **FIGURE 62.5**)
    - Defect is caused by the linea alba.
    - Anywhere along the linea alba from the xyphoid to the umbilicus
    - Majority in adults
    - Small and usually peritoneal fat
  - Umbilical (5%–10% of children; **FIGURE 62.6**)
    - Defect is that of the fibromuscular ring of the umbilicus.
    - Ten times more common in women
    - Usually in infants and children and resolves by the age of 5 years
    - Only 5% persist into later childhood and adulthood
    - An acquired variant may be seen in adults with increased abdominal pressure:
      - Obesity
      - Ascites
      - Pregnancy
        - ❑ Incarceration/strangulation more common in adults.
  - Incisional (15%–20%; **FIGURE 62.7**)
    - Defect is a previous surgical site.
    - Occur in 20% of all abdominal surgeries
    - Previous surgical scar area
    - Risks include
      - Post-op
      - Obesity
      - Advanced age
      - Post-op wound infections

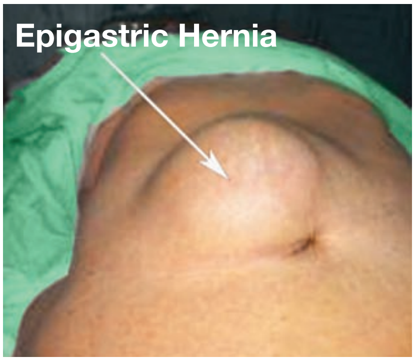


FIGURE 62.5 Epigastric hernia.

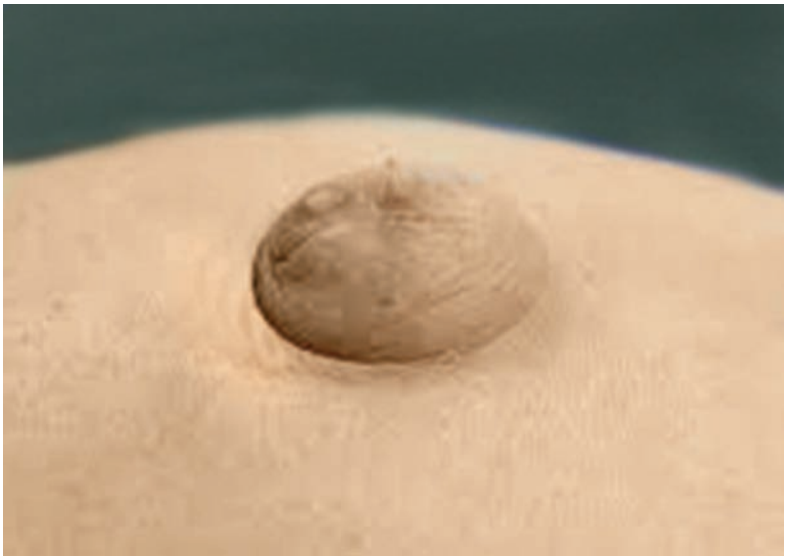


FIGURE 62.6 Umbilical hernia.

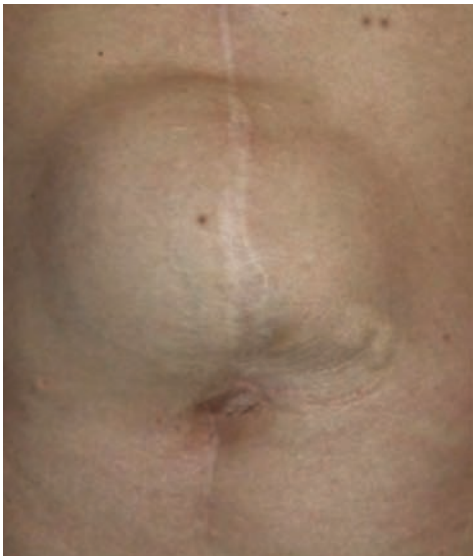


FIGURE 62.7 Incisional hernia.

- Femoral hernias (5%; **FIGURE 62.8**)
  - Defect is the transversalis fascia.
  - Occur below the inguinal ligament
  - Medial to the femoral vein
  - Medial thigh bulge
  - 60% present on the right side
  - ***More common in women***
  - ***High risk for complication***
    - 40% rate of incarceration/strangulation
  - Mandates a close surgical follow-up
- Spigelian hernias (1%; **FIGURE 62.9**)
  - Defect is the transverse abdominal aponeurosis/fascia between the lateral edge of the rectus muscle and the semilunar line laterally.
  - Older adults
  - Usually omentum
  - 20% incarceration
- Hypogastric (<1%; **FIGURE 62.10**)
  - Usually females
  - Constant, always appearing at the level of the arcuate line in the linea alba
    - Below the umbilicus
    - Midline
  - Rare

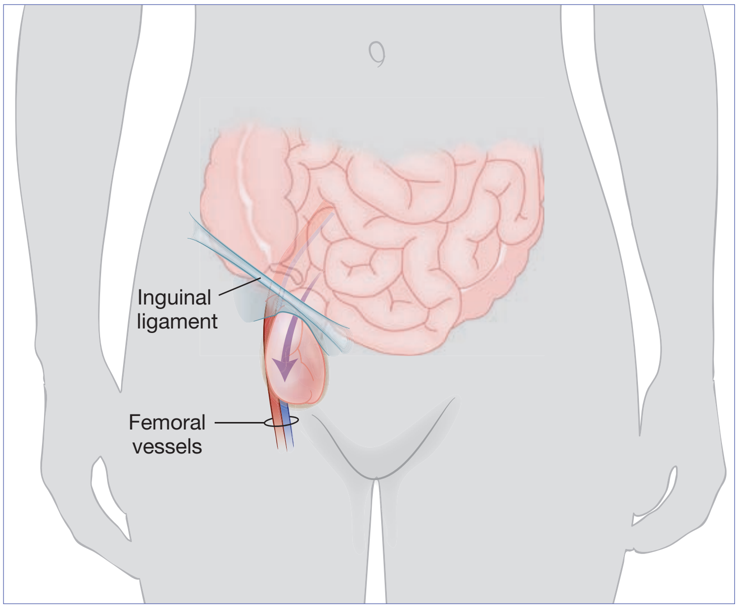


FIGURE 62.8 Femoral hernia.

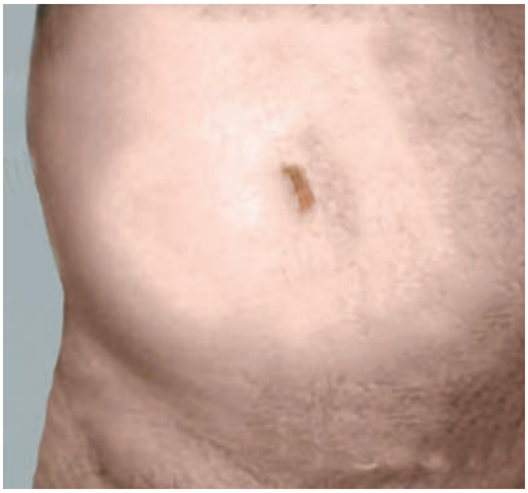


FIGURE 62.9 Spigelian hernia.

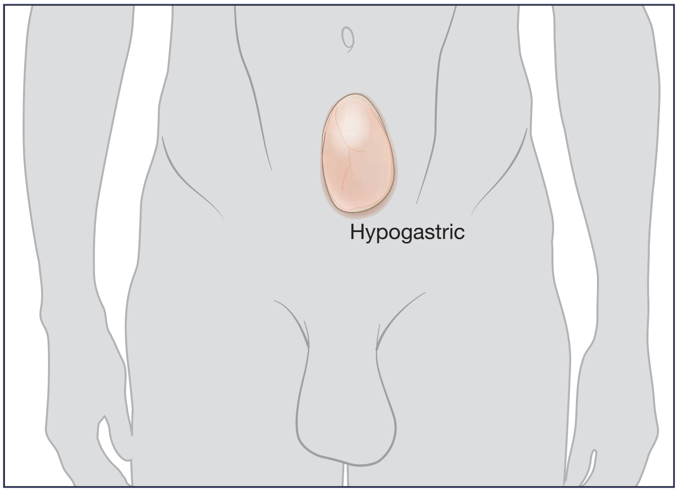


FIGURE 62.10 Hypogastric hernia.

Obturator Hernias (<1%)

- Defect is the obturator foramen in the pelvic floor
- Extremely rare
- Nine times more common in women
- Nicknamed "little lady's hernia"
- Presents as an acute small bowel obstruction
- Only treatment is surgery
- Presents with signs and symptoms of bowel obstruction
- ***Most often occur in elderly females***
- ***High risk for complication***
  - Small bowel obstruction (SBO)
  - Strangulation/incarceration
- Immediate surgical consultation

More pragmatically, hernias are further classified as:

- Sliding—Spontaneously reduces without manual maneuvers
- Reducible—Contents of the hernia sac may be manually replaced back through the tissue defect
- Incarcerated—Hernias that cannot be reduced without surgical intervention
- Strangulated—Incarcerated hernias with evidence of vascular compromise to the contents within the hernia sac (**FIGURE 62.11**)
- Richter's—Herniation of the antimesenteric wall of the intestine through an abdominal defect; ***one side of the bowel wall can necrose without signs of obstruction***

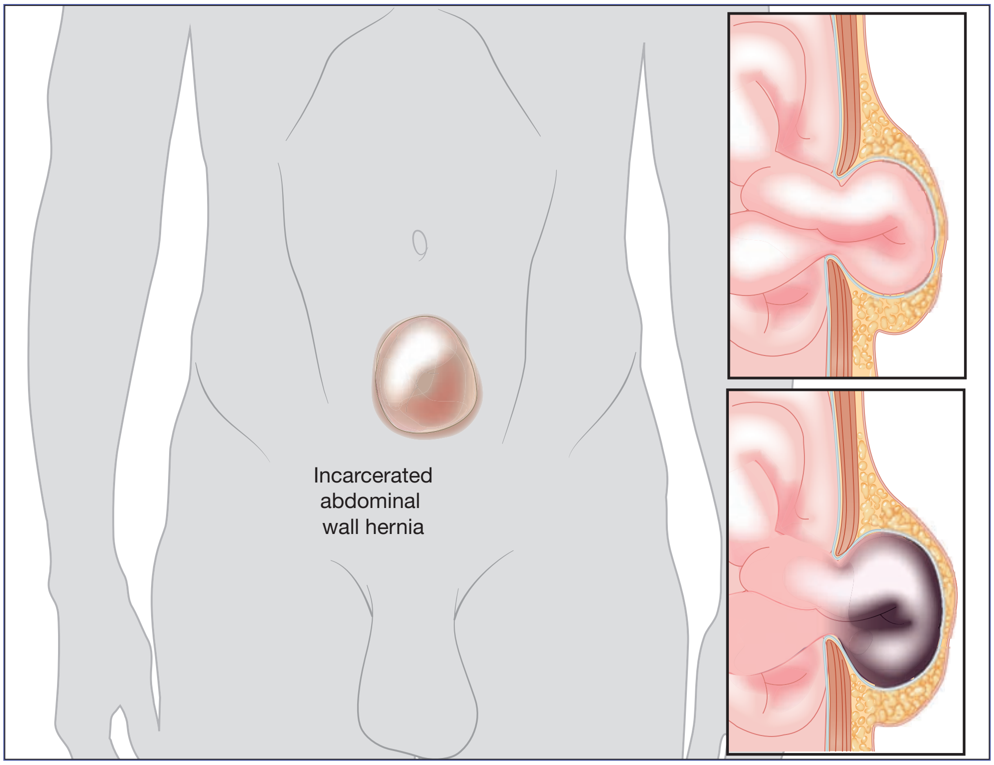


FIGURE 62.11 Progression of an incarcerated abdominal wall hernia into a strangulated hernia. When the vascular integrity of the bowel is in question, do not reduce as this is a surgical emergency. Bowel infarction and peritonitis will ensue without expedient surgical treatment.

Radiographic Imaging

Hernia is usually a clinical, bedside diagnosis. However, when presentations are unclear or when looking for the sequela of bowel obstruction, intestinal perforation and secondary signs of strangulation, medical imaging may be necessary. Note, as a rule, strangulation is a bedside diagnosis. CT scan is the diagnostic test of choice, especially for hernia-related complications (**FIGURE 62.12**)

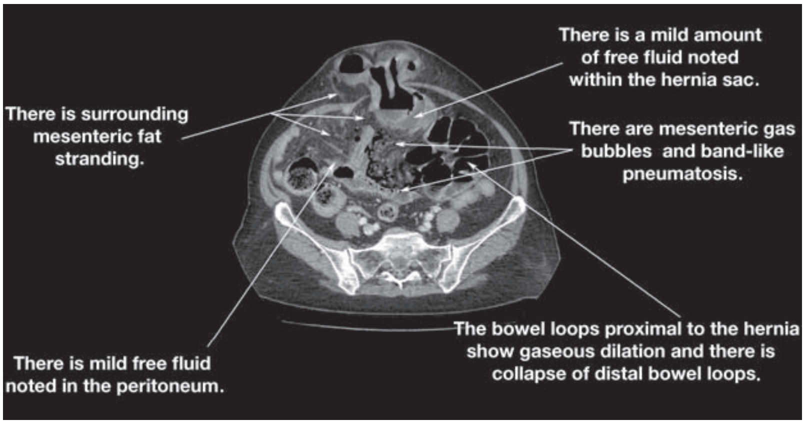

There is a mild amount of free fluid noted within the hernia sac.
There is surrounding mesenteric fat stranding.
There are mesenteric gas bubbles and band-like pneumatosis.
There is mild free fluid noted in the peritoneum.
The bowel loops proximal to the hernia show gaseous dilation and there is collapse of distal bowel loops.

FIGURE 62.12 CT of strangulated hernia with bowel ischemia. There is an anterior abdominal wall defect through which small bowel loops and omentum are protruding out of the abdominal cavity in a C-shaped configuration. The bowel loops involved in the hernia show wall thickening.

Point-of-Care Ultrasound

In a patient presenting with a new abdominal or scrotal mass for which the diagnosis is unclear, point-of-care ultrasound (POCUS) is useful in diagnosing a hernia. Robinson, Light, and Nice (2013) in a meta-analysis of inguinal hernias composed of nine studies have shown that the pooled sensitivity, specificity, and positive predictive value (PPV) were 97%, 85%, and 93%, respectively. Clinicians may visualize:

- Hyperechoic sac-like structures consistent with bowel wall.
- Peristalsis and shadowing consistent with bowel contents using a high-frequency linear probe.
- *Dynamic ultrasound with Valsalva maneuver, which may improve imaging findings and facilitate the diagnosis of a hernia* (**FIGURE 62.13**).

Sonographic signs of incarceration and/or strangulation (**FIGURE 62.14**):

- Free fluid in the hernia sac
- Absent peristalsis
- Thickened loops of bowel

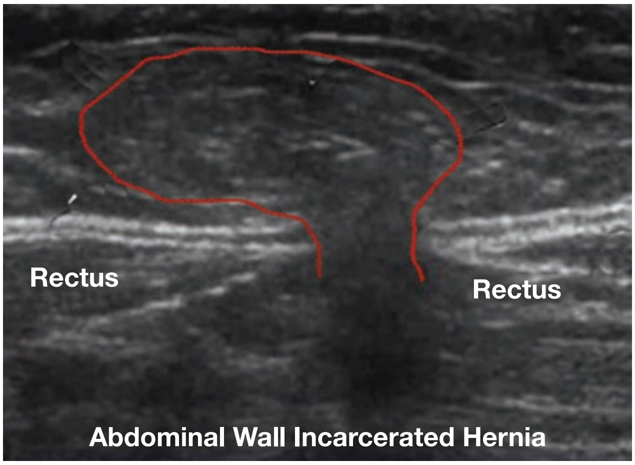

Rectus
Rectus
Abdominal Wall Incarcerated Hernia

FIGURE 62.13 Abdominal wall incarcerated hernia.

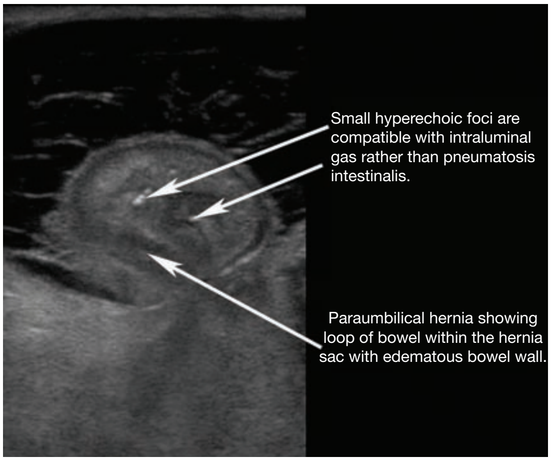

Small hyperechoic foci are compatible with intraluminal gas rather than pneumatosis intestinalis.
Paraumbilical hernia showing loop of bowel within the hernia sac with edematous bowel wall.

FIGURE 62.14 Incarcerated/strangulated paraumbilical hernia displaying sonographic signs of bowel ischemia.

PATIENT PRESENTATION

- Patients may present with a new protrusion or mass in the inguinal, anterior abdominal wall, or femoral regions, as well as at the site of prior surgical incisions.
- Patients may have a mass that increases in size and/or pain when performing a Valsalva maneuver or experiencing bowel movements.
- Patients may experience some discomfort related to the protrusion.
- Patients with incarcerated hernias may present with a firm, painful mass, which is not readily reduced through the abdominal wall defect.
- Severe, acute pain at the hernia site should raise clinical suspicion for strangulation. Strangulated hernias suggest the presence of underlying vascular compromise to the hernia sac contents (ischemic bowel) and may have the associated symptoms of bowel obstruction, including nausea and vomiting.
- Overlying skin changes may also occur in the presence of a strangulated hernia (**FIGURE 62.15**).
  - Erythema
  - Purple color

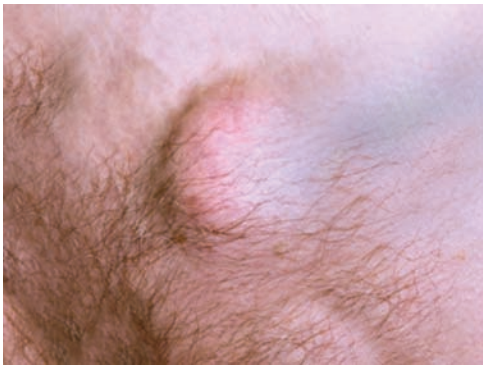


FIGURE 62.15 Strangulated inguinal hernia. Note erythema of the overlying skin, tenderness, and inability to reduce.

TREATMENT

- Sliding
  - Manual closed reduction
- Incarcerated hernias
  - Immediate manual closed reduction
- Strangulated
  - Suspicion of strangulated hernia warrants surgical consultation
  - Broad-spectrum antibiotics
  - Crystalloid fluid resuscitation

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Suspicion for strangulated hernia should preclude attempts at bedside manipulation and warrants early surgical consultation. If the diagnosis of hernia is unclear, further confirmatory imaging, including POCUS and/or CT, may be required prior to attempted manual closed reduction.

SPECIAL CONSIDERATIONS

None.

PROCEDURE PREPARATION

Integral to success in this procedure is adequate patient analgesia and positioning prior to attempted reduction. Patient comfort and relaxation during the procedure will allow clinicians to use adequate manual pressure as well as decrease the muscular tone in order to better facilitate successful reduction.

PROCEDURE

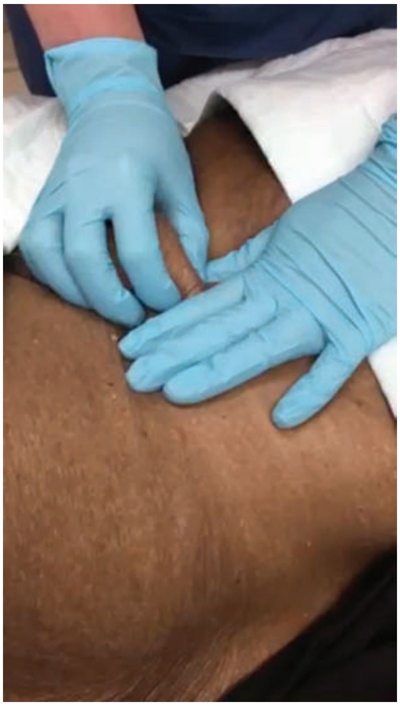
The patient should be positioned in Trendelenburg for inguinal hernias or supine for ventral reduction so that gravity can assist with reduction of hernia sac contents. With appropriate analgesia, sedation, and positioning, many hernias may reduce spontaneously without additional manipulation.

Spontaneous reduction has been reported in up to 80% of inguinal hernias over a 2-hour period using appropriate patient positioning/relaxation without manipulation. Clinicians may also consider ice or cool compresses to reduce swelling in the area prior to manipulation.

Once adequate patient comfort has been achieved, the practitioner should palpate for the distal edge of the tissue defect and support the contents of the hernia sac at this tissue edge while applying steady, firm pressure to the proximal contents of the hernia sac closest to the fascial defect (**VIDEO 62.1**, **FIGURES 62.16** and **62.17**).

Care should be taken not to simply push on that part of the hernia sac that is most superficial and closest to the clinician. This will only lead to a lateral bulging of the sac beyond the width of the hernia neck, which tends to lead to an unsuccessful reduction attempt.

Successful reduction may be evaluated by improved patient comfort, direct palpation of the fascial defect, disappearance of the tissue firmness/bulge, or by bedside ultrasound.



VIDEO 62.1 Closed manual reduction of an inguinal hernia.

ULTRASOUND GUIDANCE

Although dynamic ultrasound guidance may be used during this procedure, more commonly, static images are acquired pre- and postmanipulation to confirm successful reduction.

POSTPROCEDURE CONSIDERATIONS

- Observation for re-occurrence
- Assessment for retroperitoneal hematoma

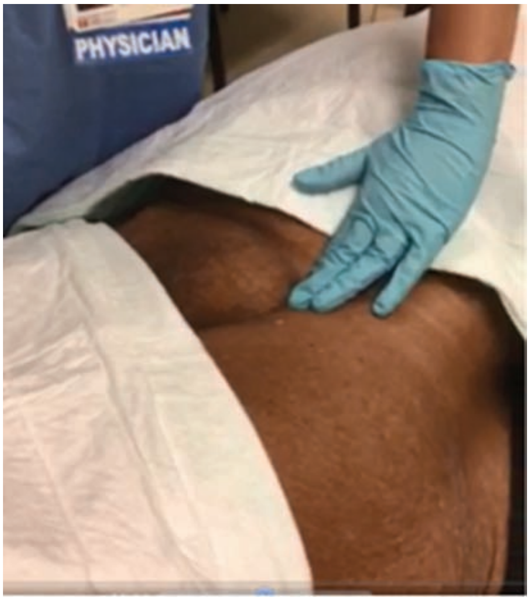


FIGURE 62.16 Palpate for edge of tissue defect prior to attempted reduction.

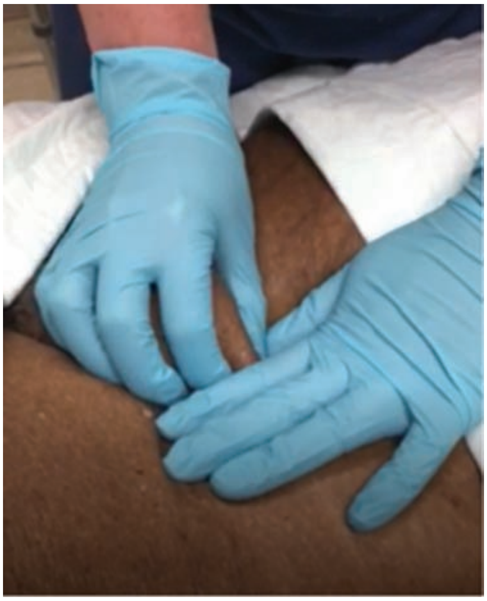


FIGURE 62.17 Firm pressure is applied to the proximal contents of the hernia sac with opposing support at the distal defect edge to prevent ballooning of the tissue over and beyond the hernia defect.

EDUCATIONAL POINTS

- Patients successfully treated via a manual closed reduction for an incarcerated inguinal hernia should be referred to general surgery to discuss conservative versus operative management.
    - ***Although referral for all patients is appropriate, patients presenting with incarcerated femoral hernia are at high risk for strangulation and should have expedited referral in anticipation of operative management.***

COMPLICATIONS

Complications of repeated manipulation of incarcerated hernias can include:

- Strangulation represented by worsening swelling and pain.
- Incomplete reduction of the hernia sac contents into the interposed tissues rather than completely through the fascial defect represented by ongoing pain after reduction.
- Reduction of infarcted bowel into the peritoneal cavity represented by ongoing pain and peritonitis.

PEARLS

- Do NOT reduce a strangulated hernia, which can result in perforation and sepsis if strangulated.
- Preprocedural positioning and patient analgesia are critical to successful manual reduction.
- All patients with bowel obstructions must be evaluated for abdominal wall hernias, especially those with no prior surgical history.
- No abdominal exam is complete without examining the groin for potential inguinal hernia/testicular torsion that is referred pain.
- Firm, ongoing pressure directed at reduction of contents proximal to the tissue defect with a supporting hand at the opposing distal edge improves successful reduction by limiting displacement of proximal contents over the edge of the tissue defect.
- Red-flag symptoms/sign of strangulation mandating immediate surgical consultation:
    - Nausea and vomiting
    - Overlying skin changes (erythema)
    - Acute onset of pain
    - Peritoneal signs
- All patients presenting with a hernia should be referred to general surgery for further evaluation; however, patients presenting with obturator or femoral hernias are at high risk for complication and should have expedited follow-up.

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CHAPTER

63

Procedures for Treating a Hair Tourniquet

Lee Ann Boyd and M. Bess Raulerson

BACKGROUND

A hair tourniquet occurs when a hair or thread entraps an appendage; it can lead to pain, injury, and possible loss of function or loss of the appendage. Epithelialization may occur at the site of the hair or thread, impairing the ability to visualize the tourniquet. Therefore, the clinician must remain astute to the possibility of a hair tourniquet even when not visible in scenarios with a high clinical suspicion. Hair has the ability to stretch when wet and contract as it dries. Hair's tensile strength causes ischemic compression as well as a direct cutting action of the appendage. A hair tourniquet is typically accidental; however, incidences of intentional cases consistent with child abuse have been cited in the literature.

Hair tourniquet syndrome (HTS) may involve fingers, toes, earlobes, nipples, tongue, scrotum, penis, and even the labia (**FIGURE 63.1**). HTS involving female genitalia, including the labia minora and clitoris, are extremely rare but should always be a consideration in the older female patient (Ihara, Takei, Kishibe, & Nomura, 2018; Imam, Florez, Beland, Swana, & Rich, 2019; Zhong & Bhattacharyya, 2017.

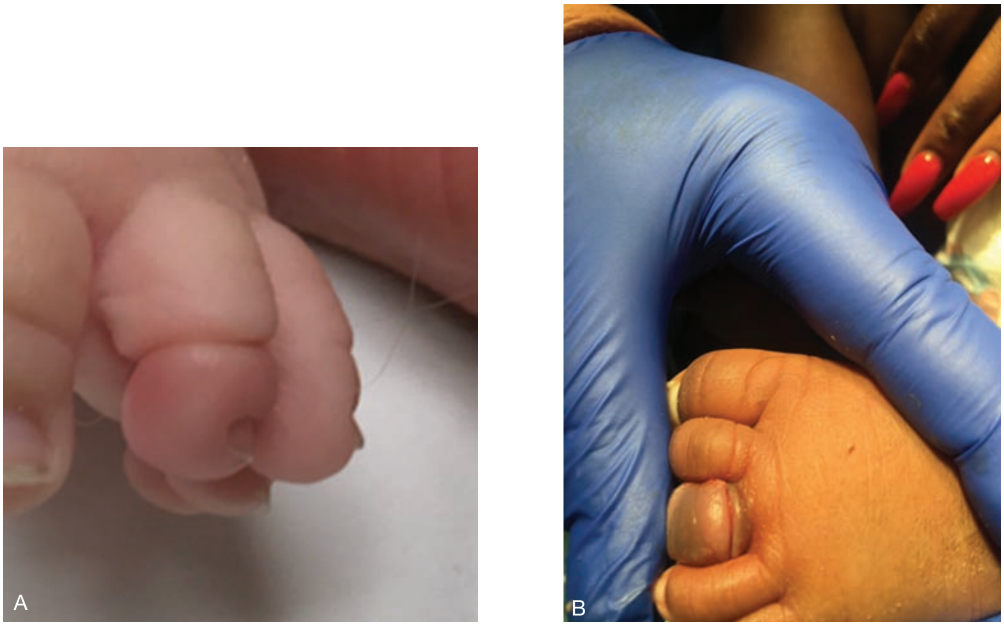

FIGURE 63.1 Photographs showing hair tourniquet on toes. (A) Note hair tourniquet to toe with swelling. (B) Multiple strands of hair wrapped around toe were removed by cutting and unwinding. Note resulting epithelialization and tissue damage.

Most cases involve the fingers and toes, followed by external genitalia (33% of cases). Infants younger than 4 months of age may be at increased risk for development of a hair tourniquet as many mothers experience postpartum hair loss several months after delivery. Our discussion regarding treatment focuses on penile hair tourniquet removal but the procedure is the same regardless of the site of the tourniquet.

High-resolution bedside ultrasonography can be utilized to identify a hair tourniquet if it is not easily visualized but there is high suspicion. One would visualize a thickened epidermis with hyperechoic area within the dermis (**FIGURE 63.2**).

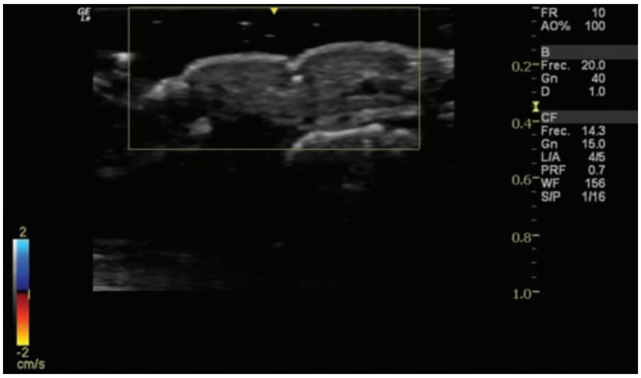

FIGURE 63.2 A thickened epidermis with hyperechoic area within the dermis is indicative of an object/strand(s) of hair.

Source: Reproduced with permission from Sebaratnam, D. F., & Hernández-Martin, A. (2018). Utility of ultrasonography in hair-thread tourniquet syndrome. *Pediatric Dermatology, 35*(2), e138-e139. https://doi.org/10.1111/pde.13400

PATIENT PRESENTATION

- Inconsolable crying in the infant
- Painful, edematous appendage
- Presence of sharp circumferential demarcation
- Cyanosis of the appendage distal to the hair tourniquet may occur (**FIGURE 63.3**)

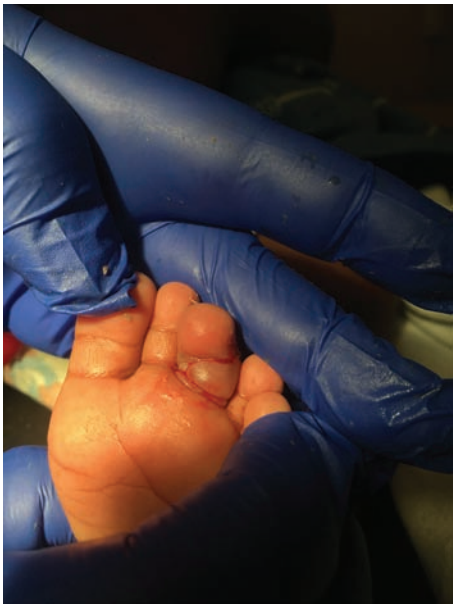

FIGURE 63.3 Demonstrating patient presentation with hair tourniquet.

TREATMENT

Treatment of a hair tourniquet consists of removal of the hair/thread. The simplest treatment is the use of depilatory creams or the unwrapping technique. Depilatory creams are thioglycolate based, the mechanism of action of which is to break the bonds of keratin in hair. They are not effective for thread tourniquets and should not be used on open skin.

If mild to moderate edema is present, the blunt probe cutting technique may be used. The hair or thread must be visible and not too deeply constrictive in the soft tissues. If the preceding treatments are unsuccessful, or severe edema or epithelialization has occurred, the incisional approach may be necessary.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- A history of an allergic reaction to depilatory creams
- Use caution with the incisional approach in patients with bleeding diathesis.

SPECIAL CONSIDERATIONS

- All patients treated for penile hair tourniquet should follow up with a urologist within 24 to 48 hours after the tourniquet has been removed.

PROCEDURE PREPARATION

Prior to initiating treatment to remove the hair tourniquet, you will need to discuss the procedure, potential complications, risks, and benefits with the patient's parents. Instruct the parents on the importance of follow-up and the expected time to return to the treatment center or primary care clinician.

Unwrapping Method

- Gloves
- Hemostat or fine-tipped forceps

Depilatory Method

- Gloves
- Depilatory cream

Cutting Method

- Gloves
- Topical or infiltrative anesthetics
- Chlorhexidine or povidone-iodine skin cleanser
- Fine-tipped scissors
- Fine-tipped hemostat
- Blunt probe
- No. 11 scalpel blade with handle

PROCEDURE

Unwrapping Method

- Position the patient for maximum visualization of the genitals.
- Most effective when only minimal edema is present, and hair/thread is readily identifiable.
- Put on clean gloves.
- Identify the free end of the hair/thread. If unable to isolate a free end, but a knot is present, break one end of the knot and proceed as follows.
- Grasp the free end of the hair with fine-tipped forceps or a hemostat, and unwind the hair from the appendage.

Depilatory Method

- No anesthesia is required.
- Apply depilatory cream directly to the hair, being careful to avoid the urethral meatus, and allow the cream to sit according to the manufacturer's instructions, typically 3 to 10 minutes.
- After breakage of the hair has occurred, wash off the area with soap and water.

Blunt Cutting Technique

- Gently insert a blunt probe underneath the hair/thread, separating the tourniquet from the skin (**FIGURE 63.4**).
- Once the thread is isolated, cut the hair/thread with fine-tipped scissors or a No. 11 scalpel blade, cutting against the surface of the probe to protect the skin.
- Proceed with the removal of the remaining tourniquet material using the unwrapping method described previously.

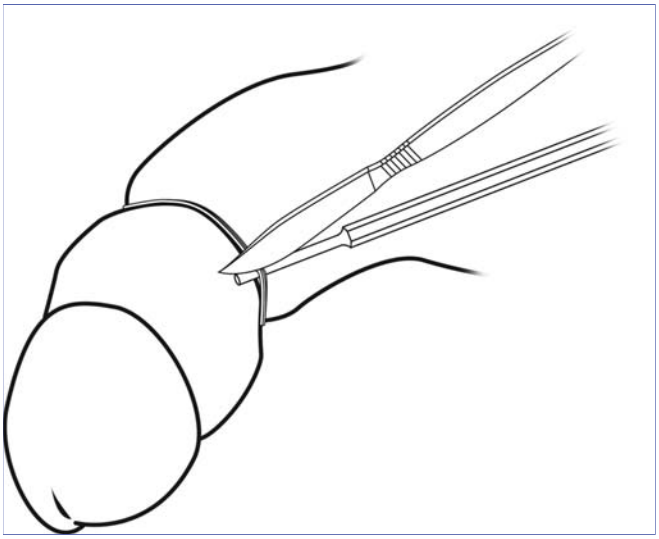

FIGURE 63.4 Use of a blunt probe to lift hair or thread tourniquet from shaft of penis prior to cutting.

Incisional Approach

- Standard precautions should be used at all times.
- To remove debris and bacteria, cleanse the skin with chlorhexidine solution or povidone-iodine in a circular motion.
- Apply a fenestrated drape over the external genitalia.
- A dorsal nerve block is recommended. Topical anesthetics, such as EMLA cream, may be used in addition to the nerve block. For a penile nerve block, please see Chapters 64 and 65.
- Once the area is anesthetized, make a small longitudinal incision with a No. 11 scalpel blade in the inferolateral surface of the phallus at the 4 or 8 o'clock position. This avoids the dorsal neurovascular bundle (**FIGURE 63.5**).
- Care should be taken to stay superficial to the deep penile fascia (Buck's fascia) in order to avoid the corpora cavernosum and spongiosum.
- Ensure the removal of all thread/hair tourniquet.

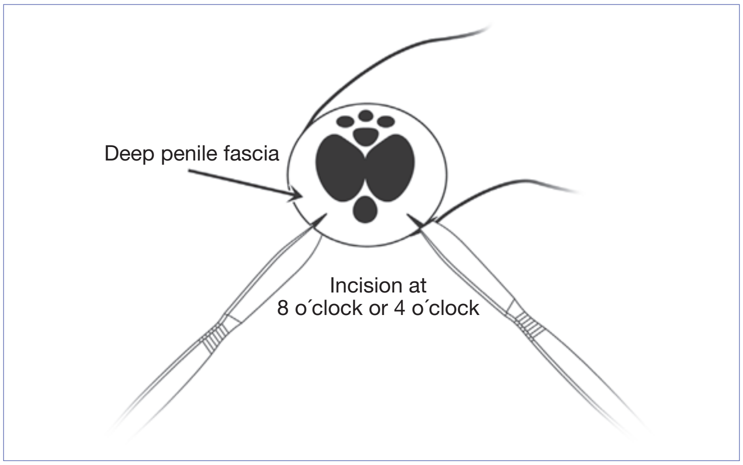

FIGURE 63.5 Crosscut view of penis just distal to "hair" tourniquet, demonstrating appropriate depth and position of incision.

POSTPROCEDURE CONSIDERATIONS

- Assess neurovascular status following the procedure.
- Administer tetanus prophylaxis if indicated.
- Antibiotic therapy should be reserved for those patients who present with localized signs of infection, or those who are diabetic or immunocompromised.
- Pediatric patients should be assessed for child neglect or abuse.
- Urology consultation should be obtained for all tourniquets involving the penis.

EDUCATIONAL POINTS

- Instruct the patient/parents on signs of infection, such as redness or increased warmth of tissue, purulent discharge, or fever, and to report these symptoms to their healthcare provider.
- Instruct the patient/parents on signs of neurovascular compromise, such as loss of sensation, coolness of the tissue, bleeding, or dusky color to the skin distal to the site of the injury, and to report any such signs to their healthcare provider.
- Report any difficulty eliminating urine or hematuria to the healthcare provider.
- Instruct on the importance of following up with the healthcare provider.

COMPLICATIONS

- Skin irritation or contact dermatitis can occur with the use of depilatory creams.
- With the incisional method, bleeding, infection, or damage to underlying neurovasculature structures can occur (i.e., urethra, corpus callosum, corpus spongiosum).
- Ischemic changes can lead to necrosis of tissue distal from the tourniquet site.

PEARLS

- The unwrapping techniques and depilatory creams are often ineffective in the clinical setting.
- In the case of symptomatic HTS, typically the blunt cutting technique or the incisional approach is necessary.
- Always check for HTS in an infant with inconsolable crying (**FIGURE 63.6**).

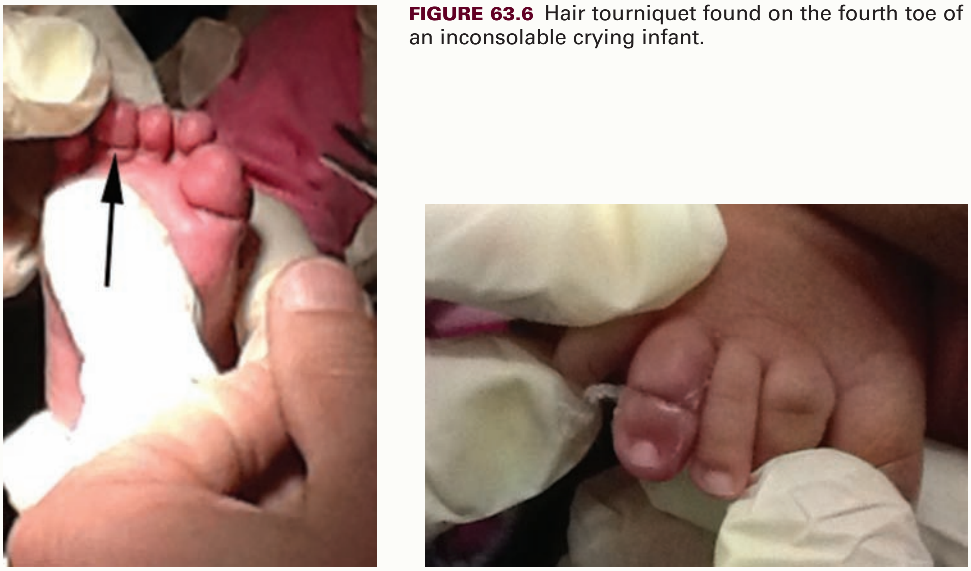

FIGURE 63.6 Hair tourniquet found on the fourth toe of an inconsolable crying infant.

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CHAPTER

64

Procedures for Treating Phimosis and Paraphimosis

M. Bess Raulerson and Keith Lafferty

PHIMOSIS

BACKGROUND

Phimosis is a narrowing of the opening of the prepuce (foreskin) in uncircumcised patients that prevents the prepuce from being retracted back over the glans penis. In young children, phimosis is actually normal or physiologic secondary to adhesions between the prepuce and glans. Note that data from the National Hospital Discharge Survey (NHDS) show that the circumcision rates in the United States declined from an all-time high of 80% in the mid-to-late 1960s to 58% in 2010. In adults, phimosis is pathologic and caused by inflammatory conditions that lead to scarring of the distal preputial orifice. When evaluating a pediatric patient with a phimosis, take into account the age of the child as the foreskin gradually becomes retractable over a variable period of time ranging from birth to 18 years of age or more; this is aided by erections and keratinization of the inner epithelium. The pediatric incidence is:

- Normal in newborns
- 20% incidence in those males 6 months of age

However, 2% of normal males continue to have nonretractability throughout life even though they are otherwise normal. In this scenario, physiologic phimosis, the distal portion of the foreskin is healthy and separates with gentle traction and the narrowed part is proximal to the preputial tip. This differs from pathological phimosis wherein gentle traction leads to formation of a cone-shaped structure with the distal narrow part being white and fibrotic; also, the meatal opening is the size of a pin-point. It is important to distinguish between these two types of phimosis because their treatment varies from a more conservative approach with physiologic phimosis, to surgical management with pathologic phimosis. Clinical features distinguishing the two include the following:

Physiologic Phimosis

- Involves only nonretractability of the foreskin (**FIGURE 64.1A**).
- There may be some ballooning during urination, however:
  - Pain, dysuria, and local or urinary infections are not seen in these cases.
- On gentle traction, the prepuce puckers and the overlying tissue are pink and healthy.
  - In general, the preputial outlet is usually closed and one cannot see the glans unless the foreskin is retracted.
- The inner preputial mucosa can be easily everted through the outlet.

Pathologic Phimosis

- There is usually pain, skin irritation, local infections, bleeding, dysuria, hematuria, frequent episodes of urinary tract infections, preputial pain, painful erections and intercourse, and weak urinary stream (**FIGURE 64.1B**).
- The meatal opening is small and the tissue in front of the foreskin is white and fibrotic.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

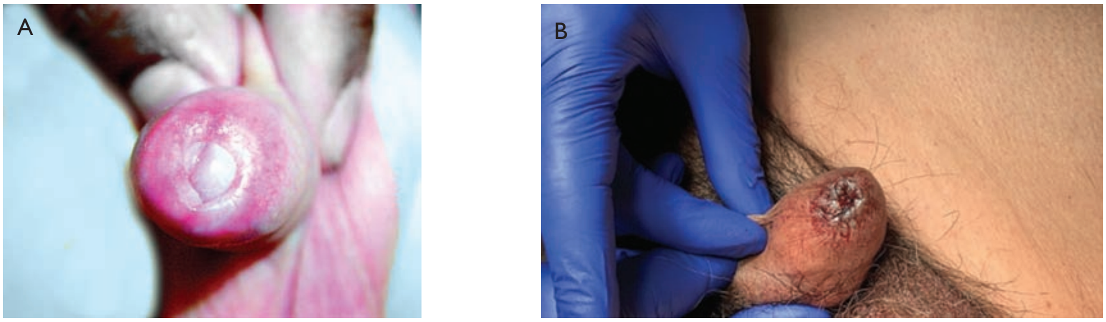


FIGURE 64.1 (A) Physiologic phimosis. Note that upon retraction, the glans and meatus are easily seen as well as the inner prepuce. (B) Pathological phimosis with adherent prepuce and partially obscured urethral meatus presented in acute urinary retention.

- In general, the glans and meatus are visible without any attempt at retraction, as the scarred ring holds the preputial outlet open.
- There is no inner mucosal eversion through the outlet.

As stated previously, the inability to retract the foreskin in a pediatric patient requires no treatment in the absence of symptoms. Phimosis persisting into late adolescence or early adulthood (2%) need not be considered abnormal but may warrant non-emergent intervention with circumcision or preputioplasty. In children, adolescents, or adults with significant symptoms or if presenting with an inability to urinate, emergent intervention is indicated.

In adults, pathologic phimosis occurs most frequently as a result of:

- Poor hygiene
- Diabetes mellitus
- Chronic and recurrent balanoposthitis
- Forceful retraction of the foreskin resulting in microtears at the preputial orifice resulting in scarring

Pathological phimosis most commonly occurs in the elderly, and lack of skin elasticity and infrequent erections are contributing factors. Patients may complain of edema, erythema, and pain of the prepuce with inability to retract the foreskin. Ballooning of the foreskin during voiding may occur, which can increase the risk of a urinary tract infection; in severe cases of tight phimosis, urinary retention may occur. A discharge may be present, which is often white to yellow in color, and is termed *smegma*.

- Smegma consists of desquamated epithelial cells that have been trapped under the prepuce.
- It is composed of sloughed epithelial cells that may form white lumps under the foreskin, commonly located around the corona.
- It is a benign condition and will eventually extrude once the foreskin becomes more retractile.

Anatomy

In uncircumcised males the penis consists of the penile shaft, glans penis with coronal sulcus (rim of the glans), and the foreskin, the physiological covering over the glans (**FIGURE 64.2**). At birth the foreskin and glans penis are fused, resulting in physiological phimosis. Over time, the epithelial cells on the inner surface of the foreskin desquamate, resulting in smegma, which causes space between the foreskin and glans, resulting in the ability to retract the foreskin. The foreskin functions to protect the glans penis and external urethral orifice, both physically and immunologically.

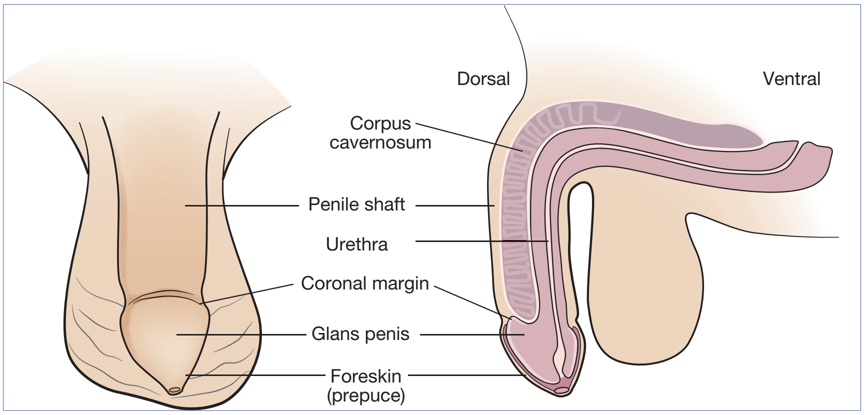


FIGURE 64.2 Penis anatomy.

PATIENT PRESENTATION

- Edema, pain, and erythema of the prepuce
- Tenderness with possible induration of the prepuce
- Discharge—White to yellow smegma
- Inability to retract foreskin
- Difficulty voiding, leading to urinary retention/foreskin ballooning in some patients with a pin-point opening on the prepuce

As with most medical disorders, pathologic phimosis is rather a spectrum of disease. Accordingly, treatment depends on the severity at presentation (**FIGURE 64.3**).

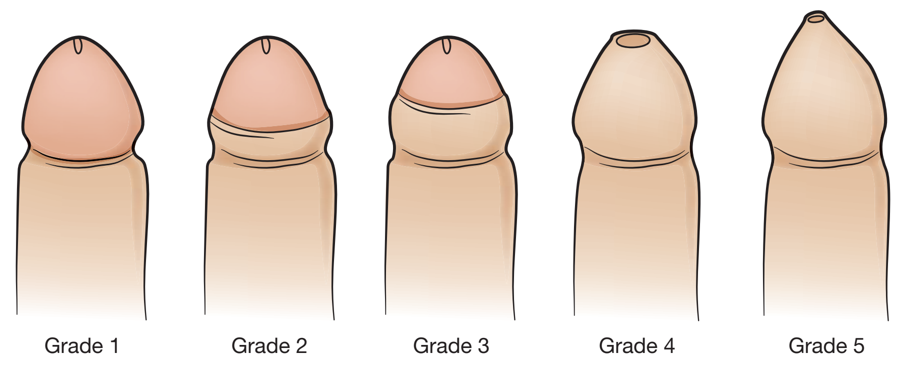


FIGURE 64.3 Degrees of phimosis. Kikiros et al. (1993) described a classification system based on increasing severity, which is as follows: Grade 0 is full retractability, Grade 1 is full retraction but tight behind glans, Grade 2 is partial exposure of glans, Grade 3 is partial retraction with meatus just visible, Grade 4 is slight retraction but neither meatus nor glans visible, and Grade 5 is absolutely no retraction.

TREATMENT

In most cases no treatment is necessary for pediatric patients with asymptomatic physiologic phimosis. Treatment of mild cases of pathologic phimosis is local treatment with topical steroids as the first line of treatment though the exact mechanism of action in this regard is mostly unknown. It is believed to act via its local anti-inflammatory/immunosuppressive action and skin thinning, as simply applying moisturizing agents has failed to yield positive results.

- Golubovic et al. (1996) compared topical steroids with petroleum and found that 19/20 males benefited with steroids, whereas only four of 20 in the petroleum group improved.
- In a Cochrane review, Moreno et al. (2014) assessed the effects of topical corticosteroids to treat phimosis in boys aged up to 18 years compared with no treatment at all.
    - Twelve studies that included 1,395 patients have shown that topical corticosteroids may increase the likelihood of full or partial resolution of phimosis without significant adverse effects.
    - Betamethasone 0.05% ointment applied at the tip of the penis at the area of the phimosis twice daily for 6 to 8 weeks has a 90% to 95% success rate. After 1 week of treatment, the foreskin should be gently retracted to aid in the release of the phimosis.

In acute or severe cases typically resulting in urinary retention, a dorsal-slit procedure may be in order. There are two acceptable procedures to perform a dorsal slit:

- Single-clamp method
- Double-clamp method
    - May provide better control and decreased risk of bleeding.
    - After appropriate preparation and administration of an anesthetic, two clamps are placed at the dorsum of the penis, being sure to avoid crushing the skin of the penile shaft.
    - The first clamp is placed at the 11 o'clock position and the second clamp at the 1 o'clock position in a V formation, with the tips of the two clamps making the base of the V.
    - Be sure that the inferior jaw of each clamp is below the phimotic ring and the superior jaw of each clamp is above the phimotic ring.
    - An assistant then holds the two clamps while pulling them apart slightly.

  - The phimotic tissue is then cut with a scalpel or iris scissors.
  - Keep clamps in place for 1 to 2 minutes and verify foreskin is retractable.
  - Once verified, remove clamps and suture edges with absorbable suture (4-0) in either interrupted or continuous fashion.
  - Apply antibiotic ointment and gauze.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Allergic reaction to betamethasone ointment
- Bleeding diathesis

SPECIAL CONSIDERATIONS

Use caution in the use of betamethasone in pediatric patients younger than 3 years—use of topical steroids has not been studied extensively in this age group.

In the case of a failed manual reduction of a paraphimosis secondary to tight phimotic ring and scarring, incising the concentric ring is indicated (see the section Paraphimosis later in this chapter).

PROCEDURE PREPARATION

As in all invasive procedures, the clinician should be donned in appropriate sterile gloves, gown, hat, and protective eyewear (**FIGURE 64.4**):

- Skin cleansing solution
- Sterile 4 × 4 gauze
- Sterile drape
- Local anesthetic or plain lidocaine
- 5-mL syringe
- 25- or 27-gauge needle
- Sterile gloves
- One or two straight hemostat clamps with teeth
- No. 15 scalpel blade or iris scissors
- 4-0 or 3-0 absorbable suture
- Topical antibiotic ointment
- Petroleum gauze
- Sterile gauze and self-adherent dressing
- Paper tape

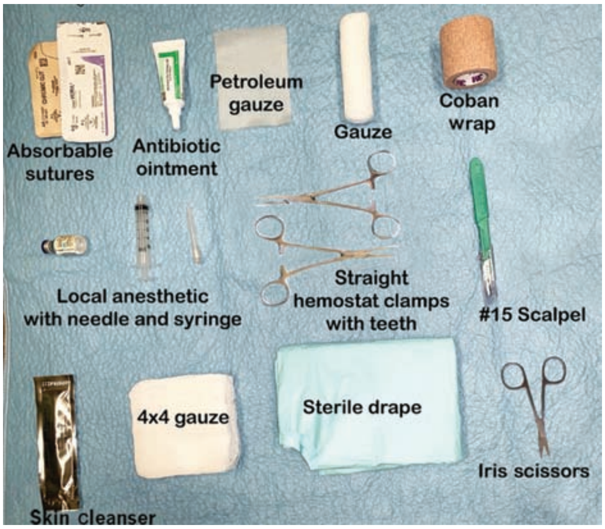


FIGURE 64.4 Equipment needed for dorsal-slit procedure.

PROCEDURE

Single-Clamp Method

- Place the patient in a supine position.
- Using aseptic technique, which is always done with appropriate personal protective equipment in place, prepare the perineal area from the suprapubic area to the scrotum using skin cleanser.
- Place a sterile drape over the genital area, exposing only the phallus.
- Fill 5-mL syringe with lidocaine and attach a 25- or 27-gauge needle.
- Anesthetize the area using one or a combination of techniques described (**FIGURE 64.5** and **VIDEO 64.1**)
  - Dorsal penile nerve block (**VIDEO 64.1A**; see also Chapter 65, Priapism)
  - Local distal infiltration
  - Penile ring block (**see VIDEO 64.1B**)
- Using a hemostat, gently separate any adhesions under the foreskin.
- Pull the dorsal foreskin taut, apply a straight hemostat (ideally with teeth) perpendicular to the corona at the 12 o'clock position, and clamp and lock the skin (**FIGURE 64.6** and **VIDEO 64.2**).
  - Hold in place for approximately 2 minutes, providing crushing of the tissue with resulting hemostasis (**FIGURE 64.6A**).
  - Local nerve tissue destruction also is a sequela of this step, which is followed by an incision of this devitalized track.
- Sharply incise the track of crushed tissue/devitalized track using a scalpel or iris scissors (**FIGURE 64.6B**).

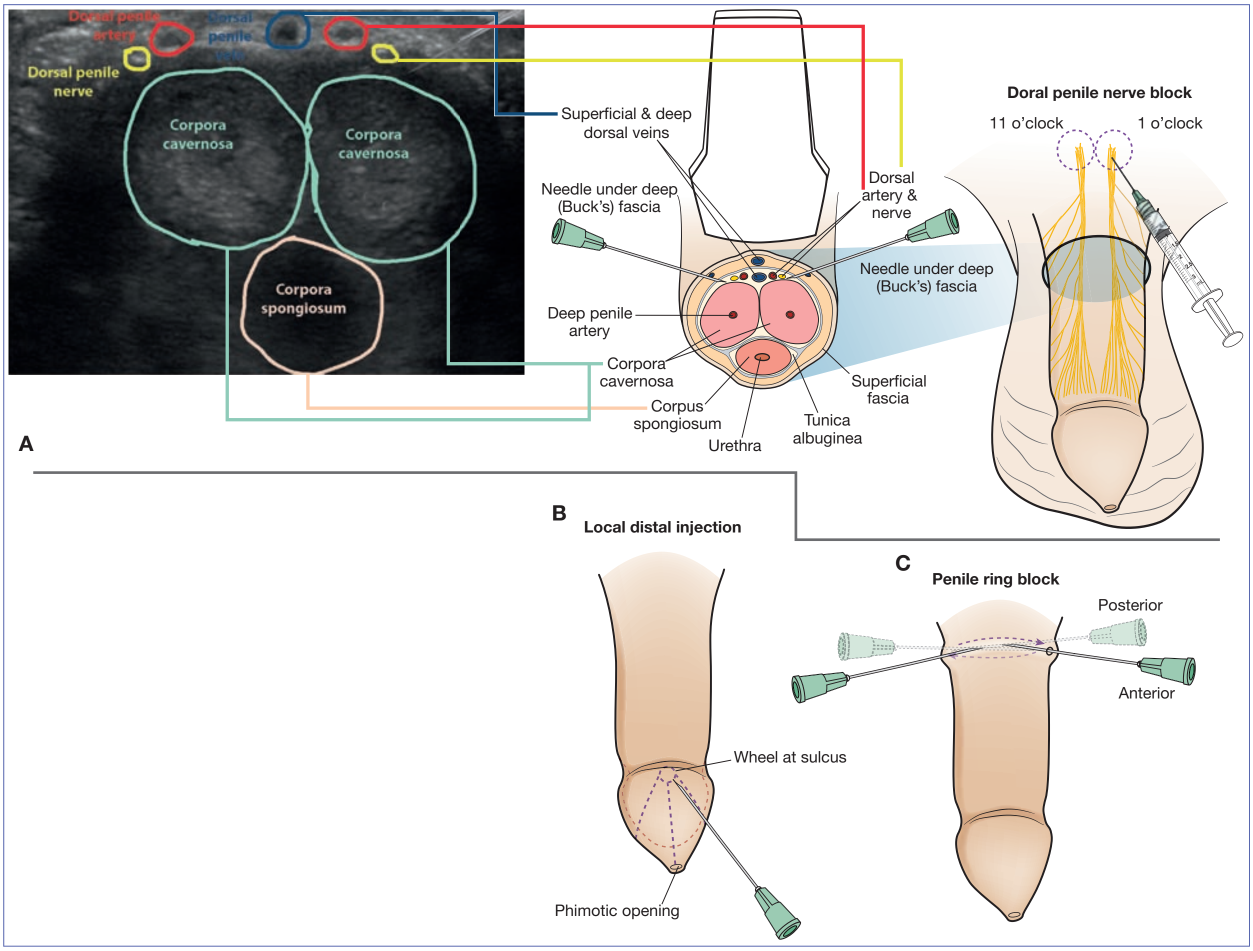
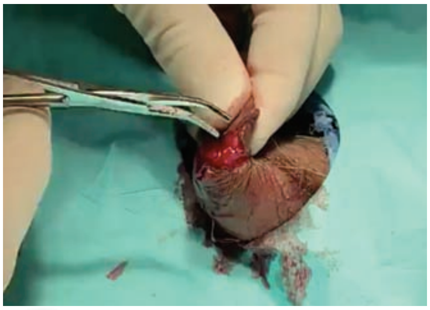

Dorsal penile artery
Dorsal penile vein
Dorsal penile nerve
Corpora cavernosa
Corpora cavernosa
Corpora spongiosum
Superficial & deep dorsal veins
Needle under deep (Buck's) fascia
Dorsal artery & nerve
Needle under deep (Buck's) fascia
Deep penile artery
Corpora cavernosa
Corpus spongiosum
Urethra
Tunica albuginea
Superficial fascia
Doral penile nerve block
11 o'clock
1 o'clock
A
B
Local distal injection
Wheel at sulcus
Phimotic opening
C
Penile ring block
Posterior
Anterior

FIGURE 64.5 Options for regional penile anesthesia include: (A) Dorsal penile nerve block aided by ultrasound (**VIDEO 64.1A**; see also Chapter 65, Priapism). (B) Local distal injection of 1% plain lidocaine into dorsal aspect of foreskin beneath superficial fascia, through the course of planned incision. (C) Penile ring block of 1% plain lidocaine beneath superficial fascia at medial aspect of dorsum of penis and continued laterally, then repeated on medial aspect of ventral aspect of penis, forming a ring (see also **VIDEO 64.1B**).

VIDEO 64.1 (A) Dorsal penile nerve block and (B) circumferential ring block.



VIDEO 64.2 Dorsal slit of a phimosis utilizing the one-clamp method.

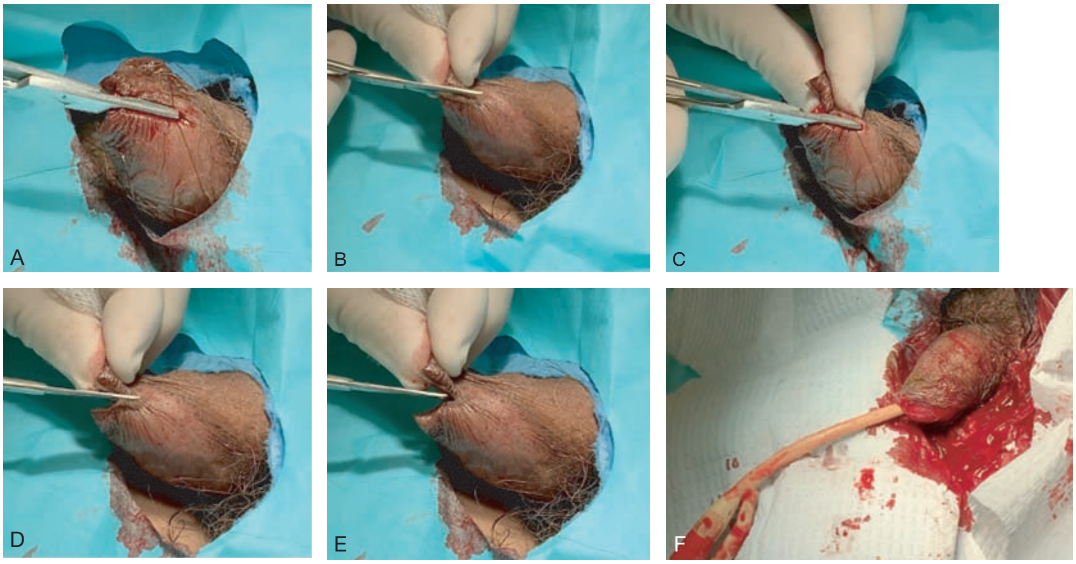


FIGURE 64.6 Dorsal slit one-clamp method for emergent treatment of a paraphimosis. Note that steps may need to be repeated in order to retract the foreskin over the glans. Patient was in urinary retention secondary to a scarred and opposed phimotic ring. Suture placement not shown.

- These steps may need to be repeated if the foreskin still cannot be retracted.
- Reduce foreskin to its natural position (**FIGURE 64.6C–E**).
- The wound edges should be approximated in a horizontal manner with absorbable suture using running (preferred) or interrupted sutures (**FIGURE 64.7**).
  - The cosmetic effects of this procedure may not be aesthetically pleasing.
  - Definitive treatment with a circumcision may be done at a later date.
- If patient is in urinary retention/unable to void, place a Foley catheter (**FIGURE 64.6F**).
- Apply topical antibiotic ointment to the suture line.
- Apply petroleum gauze and cover with sterile gauze.
- Adhere with paper tape.

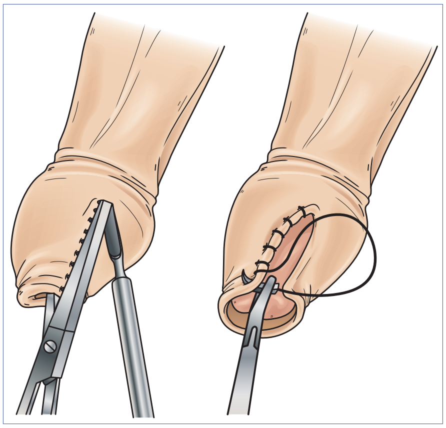


FIGURE 64.7 Dorsal slit utilizing one clamp and subsequent suturing.

Double-Clamp Method

- May provide better control and decreased risk of bleeding.
- Ensure appropriate sterile preparation and anesthesia (see previous text).
- Two straight (ideally with teeth) clamps are placed at the dorsum of the penis perpendicular to the corona.
- The first clamp is placed at the 11 o'clock position and the second clamp at the 1 o'clock position in a V formation with the tips of the two clamps meeting at the base of the V (**FIGURE 64.8A**).
- An assistant then holds the two clamps while pulling them apart slightly.
- Hold in place for approximately 2 minutes, providing crushing of the tissue with resulting hemostasis; local nerve tissue destruction also is a sequela of this step, which is followed by an incision of this devitalized track. (**FIGURE 64.8B**)
- The phimotic prepuce tissue is then cut with scalpel or iris scissors.
- Keep clamps in place for 1 to 2 minutes and verify foreskin is retractable.
- The wound edges should be approximated in a horizontal manner with absorbable suture using running (preferred) or interrupted sutures (**FIGURE 64.8C**).
  - The cosmetic effects of this procedure may not be aesthetically pleasing.
  - Definitive treatment with a circumcision may be done at a later date.

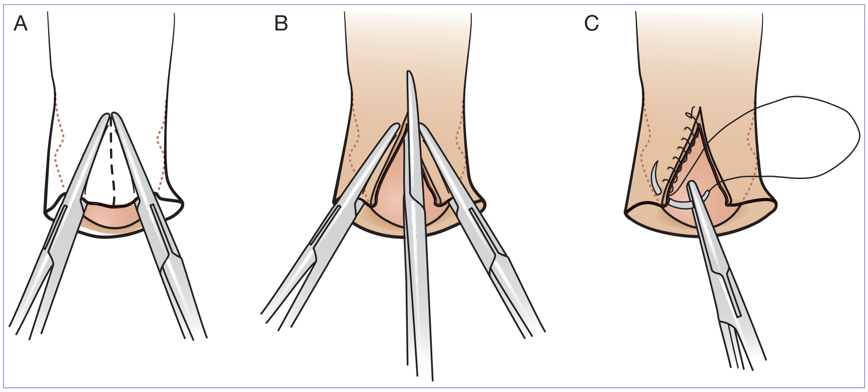


FIGURE 64.8 Dorsal slit utilizing two clamps.

- If patient is in urinary retention/unable to void, place a Foley catheter (**FIGURE 64.6F**).
- Apply topical antibiotic ointment to the suture line.
- Apply petroleum gauze and cover with sterile gauze.
- Adhere with paper tape.

POSTPROCEDURE CONSIDERATIONS

- Observe for bleeding at incision sites for 30 minutes following the procedure.
- Apply bacitracin ointment to the suture line to decrease the risk of developing adhesions during the healing process.
- Ensure patient is able to void and empty bladder by checking postvoid residual with bladder scan.
- Ensure that an analgesic prescription is given to the patient for postoperative pain.

EDUCATIONAL POINTS

Physiology

- Ensure that one performs this procedure on the dorsal aspect of the penis and not the ventral aspect, as the former carries increased risks secondary to:
  - Proximity to the urethra and risk of urethral damage.
  - Increased risk of severing the frenular artery just inferior to the urethra.
    - The frenular branch of the dorsal artery curves around each side of the distal shaft to enter the frenulum and glans ventrally.
  - Tissue on the ventral aspect of the glans, which is more adhered anatomically.
- The tip of the hemostat should be palpable under the foreskin at the coronal sulcus; use care to avoid placing the hemostat within the urethra.
- The dorsal-slit procedure is a viable option for patients who may be at risk for general anesthesia, because it is performed with local anesthesia.
- In pathologic phimosis, non-retraction is due to distal scarring of the prepuce and urologic follow-up is warranted.
- Encourage good local hygiene.
- Instruct on the removal of smegma.
- Instruct parents on gentle and gradual retraction of foreskin in the newborn.

Pathology

- Encourage good local hygiene.
- Instruct the patient/parents on the importance of completing the course of topical treatment to prevent recurrence.
- Instruct the patient/parents on the application of antibiotic ointment to the glans penis twice daily for 2 weeks to prevent formation of new adhesions following the dorsal-slit procedure.
- For diabetic patients, encourage tight control of serum blood sugar to prevent recurrence.
- No sexual intercourse for 4 to 6 weeks postoperatively.
- Definitive treatment with circumcision may be done after acute inflammation resolves.
- In pathologic phimosis, nonretraction is due to distal scarring of the prepuce and urologic follow-up is warranted.

COMPLICATIONS

- If phimosis is not treated, there is an increased risk of persistent balanoposthitis, future phimosis, and development of squamous cell penile carcinoma.
- Bleeding
- Hematoma
- Wound infection
- Glanular adhesions
- Tissue sloughing
- Urinary retention

PEARLS

- Physiologic phimosis is the rule in newborn males; the prepuce is adhered to the glans and this separates over time as 50% of the prepuces of newborns are nonretractile, whereas only 10% of 3-year-old boys and 1% of 16-year-olds will have nonretractile foreskins.
- Proper foreskin hygiene, including gentle retraction and cleansing during bathing, helps prevent the transition of physiologic to pathologic phimosis.
- Most patients who present with tight foreskins have physiologic phimosis, which will generally resolve with time and proper foreskin hygiene. A short course (6 to 8 weeks) of topical corticosteroids may help.
- Poor hygiene and recurrent balanitis (infection of glans penis), posthitis (inflammation of foreskin), or both, could lead to difficulty in retraction of foreskin and consequently pathologic phimosis.
- Diabetes mellitus predisposes to these infections due to high glucose content of urine, which is conducive to bacterial proliferation.
- Consider the serum glucose level and hemoglobin A1C to rule out underlying diabetes mellitus in adults.

PARAPHIMOSIS

BACKGROUND

Paraphimosis is the inability to completely reduce the penile foreskin distally, back to its natural reduced position overlying the glans penis, usually secondary to a tightening or constricting of the foreskin, which has been retracted behind the corona of the glans penis (**FIGURE 64.9**). ***This is a true urologic emergency***. This results in a tight constrictive band of tissue causing vascular engorgement and swelling of the glans. Prolonged retraction can

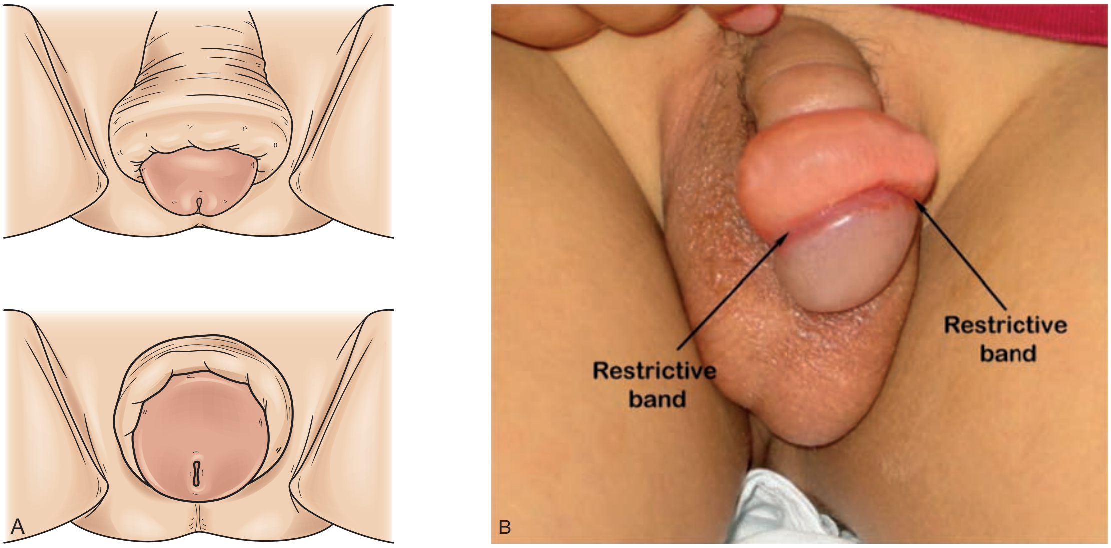


FIGURE 64.9 (A) Paraphimosis. ***This is a true urologic emergency.*** This can only occur in uncircumcised males and is less common than a phimosis. (B) Note the phimotic ring presenting in early stages before onset of ischemia.

lead to obstruction of the lymphatics and subsequent lymphedema, which impairs the ability to replace the foreskin to its normal position over the glans penis, resulting in distal tissue ischemia/necrosis (glans).

In uncircumcised children, paraphimosis occurs in 0.5% of children aged 4 months to 12 years (which is increasing as the rate of circumcision is decreasing), which is less common than other penile disorders such as:

- Phimosis (2.6%)
- Balanitis (5.9%)

In those who are older, paraphimosis is most commonly found in adolescents, with about 1% of all cases occurring in males over 16 years of age. It is often associated with:

- Poor hygiene
- Chronic balanoposthitis
- Diabetes
- Phimosis
- Sexual activity
- Iatrogenic paraphimosis
  - Phimosis
    - Physical examination if the foreskin is not returned to its native location overlying the glans
  - Urinary catheterization
    - Chronic
    - Intermittent
- Poor hygiene and balanoposthitis are also associated with development of paraphimosis.

If the constriction is severe, venous congestion of the glans is present, which can cause subsequent ischemia and eventual necrosis of the glans penis or distal urethra.

PATIENT PRESENTATION

- Presence of a tight and circumferential phimotic ring proximal to the corona (**FIGURE 64.10A**)
- Late finding of venous congestion of the glans with necrosis at the phimotic ring, which may extend to the glans penis (**FIGURE 64.10B**)

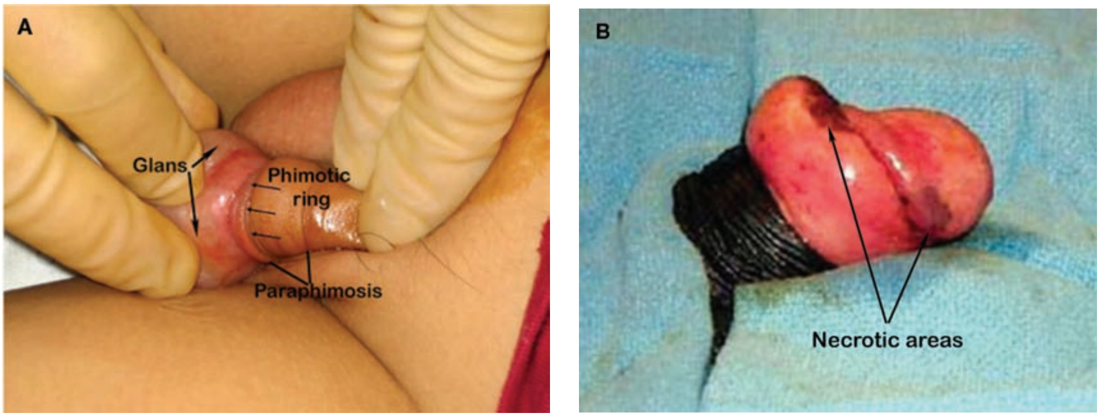


FIGURE 64.10 (A) Paraphimosis is a ***true urological emergency*** and as such must be recognized and treated promptly as the glans is at risk for necrosis in just a few hours followed by gangrene; possible amputation may ensue days to weeks later. Note the restrictive band proximal to the glans over the corona sulcus. (B) In a different patient who presented to the ED in a later stage, note areas of necrosis setting in and early gangrene, indicated by arrows.

TREATMENT

- Treatment of paraphimosis requires ***urgent and time-sensitive*** reduction of the edematous glans penis
- A stepwise approach is used from least to most invasive:
  - Manual compression
  - Dorsal slit

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- There are no contraindications to manual reduction of the paraphimosis.
- Use caution with the dorsal-slit procedure in patients with a bleeding diathesis.
- Reversal of bleeding disorders, if possible, may be indicated if impending vascular compromise is evident.

SPECIAL CONSIDERATIONS

Careful examination should be done to rule out any area of necrosis on the phallus, which would need to be debrided, and requires urological consultation.

PROCEDURE PREPARATION

Manual Decompression

- Ice
- Anesthesia
  - 1% lidocaine gel or Emla cream (2.5% prilocaine and 2.5% lidocaine)
  - Local anesthesia (see **FIGURE 64.5**)
    - Dorsal penile nerve block and penile ring block anesthesia
- Elastic wrap, Coban or Kerlix bandage

Dorsal Slit

- See **FIGURE 64.4** for equipment needed for dorsal-slit procedure.

PROCEDURE

Manual Decompression

- Anesthetize the area using local infiltration and/or perform a penile block (**FIGURE 64.5**; see Chapter 65, Priapism).
  - Alternatively, apply topical anesthetic to the tight phimotic ring using 1% lidocaine gel or Emla cream.
- Apply an ice pack to the distal phallus for 10 to 15 minutes with cloth drape in between.
- Compress the foreskin and glans with a firmly grasped hand for several minutes to reduce as much edema fluid as possible (**FIGURE 64.11**).
  - Alternatively, an elastic wrap, Coban, or Kerlix bandage can be wrapped distal to proximal, from the glans to the base of the penis, and kept in place for 5 to 20 minutes.
- Manually compress the edematous glans penis using gentle, steady pressure with both thumbs on the glans for 5 minutes (**FIGURE 64.12** and **VIDEO 64.3**).

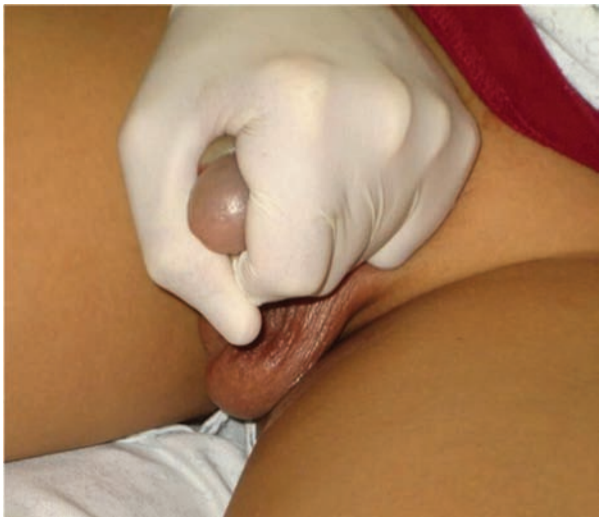


FIGURE 64.11 Compression of edematous foreskin after administration of local anesthesia ice compress and preceding manual decompression.

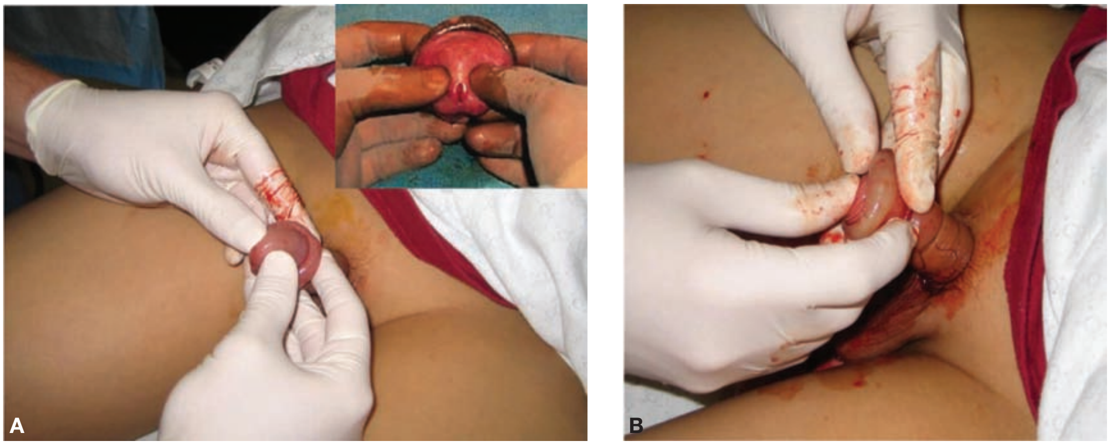


FIGURE 64.12 (A) Using two hands, place both thumbs on the glans and second and third fingers just proximal to the paraphimotic swollen foreskin. (B) Simultaneously, push the glans proximally while pushing the prepuce distally as you would turn a sock inside out. Once tissue is reduced, replace the foreskin fully to its naturally retracted position.

VIDEO 64.3 Procedure for manual reduction of a paraphimosis. Note also shown is a circumferential ring block of the penis.

Dorsal Slit

In the event that manual reduction attempts are unsuccessful, a dorsal slit is necessary to incise the constricting phimotic tissue to permit reduction of the foreskin over the glans; this is somewhat similar to the dorsal slit in the treatment of a phimosis (**FIGURE 64.13**). As in a dorsal slit in phimosis, anesthesia is required via a dorsal penile nerve block and/or a penile ring block (see **FIGURE 64.5**; see also Chapter 65).

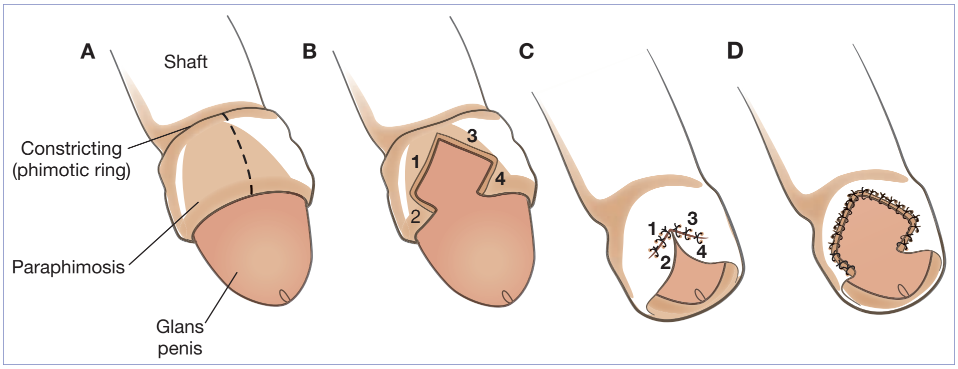


FIGURE 64.13 Pattern of incision for reduction of paraphimosis with constricting, phimotic ring. After anesthesia, incise foreskin (A), further reduce constricted tissue with lateral incisions, debriding as needed to free foreskin (B), close incision if ample tissue (C), or if significant tissue loss or continued edema (D). Optimally, the wound should be sutured, but if minimal bleeding or minimal incision, nonadherent dressing and Coban occlusive dressing can be used.

Adjunctive Techniques

Publications on these techniques are mostly observational and small.

- Dundee micropuncture technique
  - To promote drainage of edema fluid and/or blood from venous congestion, make several superficial (2–3 mm) puncture wounds using a 25-gauge needle in the edematous foreskin.
- Sugar technique
  - Use granulated sugar, with which you coat the foreskin, or gauze soaked in 50 mL of 50% dextrose that you wrap around the glans and foreskin.
  - The duration of time needed (1–2 hours) makes this unproven modality unfavorable.

POSTPROCEDURE CONSIDERATIONS

- If there is no definitive treatment, paraphimosis is likely to re-occur.
- Debridement of necrotic tissue is rarely indicated.
- Observe for bleeding for 30 minutes following a dorsal-slit procedure.
- Ensure patient is able to void.
- After the procedure it is important to carefully cleanse the foreskin and treat any abrasions or tears with antibiotic ointment.

EDUCATIONAL POINTS

- ***Paraphimosis is a urological emergency*** and ***time-sensitive treatment is indicated.***
  - Contrary to this, the more common phimosis is only an emergency when it induces urinary retention.
- The astute clinician must be wary of misdiagnosing the condition as a local allergic reaction, infection, or edema resulting from systemic volume overload (ascites, congestive heart failure [CHF], etc.).
- Patients and healthcare clinicians need to be instructed to replace the foreskin to its normal position over the glans penis after placement of a urinary catheter.
- Those patients who have a chronic indwelling Foley catheter should be taught routine catheter care with gentle soap and water, stressing the importance of returning the foreskin over the glans.
- Urological consultation for definitive treatment (circumcision) is warranted.
- Educate patient and/or caregivers to avoid retracting the foreskin for 1 week and to avoid any activities that contributed to paraphimosis for 7 to 10 days.
- Residual edema or swelling will resolve in a few days.
- Compressive dressing (i.e., self-adherent dressing over thin layer of gauze) will help with any residual edema or bleeding and must allow for visualization of the urethra to aovid impeding urination.
- Oral antibiotics are indicated if there is any evidence of ulceration or infection of the foreskin.
- Huang et al. (2016) note that phimosis with preputial fissures may be a sign of undiagnosed diabetes mellitus; in 28 patients with phimosis and preputial fissures, diabetes was confirmed in all 28 patients, as compared with only two patients out of 28 with phimosis without preputial fissures.
- Paraphimosis is less common than phimosis.
- Paraphimosis is almost always an iatrogenically or inadvertently induced condition; always unretract the foreskin after retracting it.

COMPLICATIONS

- Arterial occlusion with necrosis of the glans penis and/or the distal urethra
- Skin tears, lacerations, and bleeding
  - These should be repaired with absorbable sutures
- Recurrence
- Infection
  - Posthitis
  - Necrosis and gangrene of the distal urethra
    - Autoamputation

PEARLS

- If an indwelling Foley catheter is present, remove the catheter to aid in reduction of paraphimosis.
- A successfully reduced paraphimosis needs definitive treatment to prevent a future phimosis.
- Patient and caregivers should be reminded to return the foreskin to normal position after sexual activity and cleaning.
- If a paraphimosis is secondary to a penile piercing or other foreign body, the foreskin should not be replaced until removal of the foreign body.
- If noninvasive maneuvers are unsuccessful, a dorsal slit of the prepuce is indicated.
- Diabetes, secondary to causing chronic inflammation of the penis and foreskin, makes paraphimosis more likely.
- Catheterization that is done without the foreskin being returned to its natural position can induce a paraphimosis.
- In general, the foreskin in children does not fully retract until about 2 years of age; most retract completely by the age of 10; forcibly pulling the foreskin back before it is ready to do so can cause scarring that can subsequently lead to paraphimosis.
- Cleanliness helps prevent paraphimosis; one must clean under a retractable foreskin properly and the foreskin should be returned to its natural position after cleaning.

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CHAPTER 65

Priapism

M. Bess Raulerson, Keith Lafferty, and Michael Farney

BACKGROUND

Priapism was first described by Tripe in 1845 as a prolonged and persistent penile erection. It is unassociated with sexual interest or stimulation, lasts longer than 4 hours, and is not relieved by ejaculation. The condition can lead to permanent erectile dysfunction and ***is considered a medical emergency***, as there is a 90% erectile dysfunction (ED) rate if left untreated for 24 hours. A study of emergency department visits for priapism in the United States between 2006 to 2009 identified 32,462 visits (Kim, 2016). Ischemic priapism is a urologic emergency that is associated with a high incidence of impotence whether treated quickly or not. In these cases, ***time is erectile tissue***. It is manifested by painful, persistent penile erection that is not relieved by ejaculation. The pathophysiology resulting in priapism is a complex combination of the sympathetic and parasympathetic nervous systems. Normally, the increased arterial flow of blood into the corpus cavernosum, which is mediated by the release of nitric oxide from the terminal nerves within the penis, induces relaxation of the cavernosal tissue and results in an erection (**FIGURE 65.1**). When the cavernosal pressure and arterial pressure are equal, venous blood flow is reduced. Ischemic priapism results after several hours of this pressure. This resulted ischemia leads to acidosis, sludging of blood, and thrombosis within the cavernosal arteries. If not treated quickly, this can lead to fibrosis of the corporal tissue and irreversible impotence. Priapism can be broadly subdivided into two major types: ischemic and nonischemic. This chapter focuses on the far more common low-flow (ischemic) type.

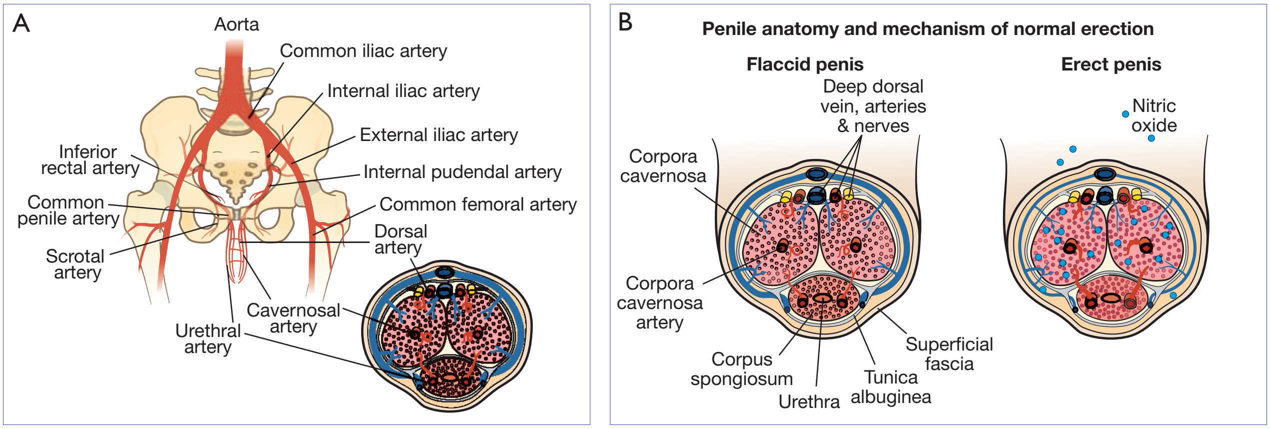

A
Aorta
Common iliac artery
Internal iliac artery
External iliac artery
Inferior rectal artery
Internal pudendal artery
Common penile artery
Common femoral artery
Dorsal artery
Scrotal artery
Cavernosal artery
Urethral artery
B
Penile anatomy and mechanism of normal erection
Flaccid penis
Erect penis
Deep dorsal vein, arteries & nerves
Nitric oxide
Corpora cavernosa
Corpora cavernosa artery
Corpus spongiosum
Urethra
Tunica albuginea
Superficial fascia

FIGURE 65.1 Cross-section of penis showing relevant anatomy. (A) The cavernosal arteries stem from the internal pudendal arteries at the crus of the penis, which originate from the internal iliac arteries. (B) Note that the central bilateral cavernosal arteries (one in each corpora) feed into the plethora of helicine arteries, which are responsible for filling the penile erectile tissue with blood after the release of nitric oxide (*shown as blue circles*) mostly from the terminal nerves, with less from the endothelium. Finally, the tunica albuginea surrounds and separates each corporis.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

Ischemic Priapism

Ischemic priapism, also termed *venoocclusive* or *low-flow priapism*, is a persistent erection marked by rigidity of the corpora cavernosa and little or no cavernous arterial inflow. It consists of an imbalance in vasoregulatory mechanisms, predisposing the penis to an ischemic environment. Mixed venous blood in the penis becomes trapped, creating venous congestion. The tissue ischemia and increased pressure generated within the corporal bodies lead to much pain. The corpora cavernosa is rigid and yet the glans penis and corpus spongiosum are generally soft.

Ischemic priapism can be summarized as follows:

- Acidotic penile blood
- Most common (95% of cases)
- Painful
- Tender shaft
- Usually iatrogenic (medications)
- Time-sensitive treatment
    - ***Compartment syndrome of the penis***

Causes include:

- Idiopathic (60%)
- Medications
    - ***ED medications—Most common of known causes***
    - Intracavernosal therapies
        - Prostaglandin E1 analogs
            - Alprostadil
        - Vasodilators
            - Papaverine
            - Phentolamine
    - Oral phosphodiesterase type 5 (PDE5) inhibitors
        - Sildenafil, vardenafil, tadalafil, avanafil
    - Trazadone
    - Antipsychotics
    - Selective serotonin reuptake inhibitors (SSRIs)
        - Fluoxetine
        - Sertraline
        - Citalopram
    - Cocaine
    - Amphetamines
    - Cannabis
    - Alpha-adrenergic antagonists
- Sickle cell disease
- Chronic myeloid leukemia (CML)
- Myeloma
- Thrombophilias
- Hypervelocity states
- Anticoagulants
- Testosterone
- Antihypertensives
    - Hydralazine
    - Prazosin
    - Doxazosin

Nonischemic Priapism

Nonischemic priapism, also termed *arterial* or *high-flow priapism*, is a persistent erection caused by unregulated cavernous arterial inflow. Nonischemic priapism generally occurs as a result of acute or remote penile trauma, creating a disruption in the cavernous arterial anatomy, resulting in an arteriocavernosal fistula. Nonischemic priapism can also result from congenital arterial malformations, or as a persistent high-flow state as a complication of shunt procedures for ischemic priapism. The cavernous environment does not become ischemic secondary to the continuous influx of arterial blood. In concordance, the corpora are tumescent but not rigid, and patients typically do not complain of pain with erection. For this reason, nonischemic priapism is not an emergency and does not require immediate intervention. Observation is first recommended and may be followed by embolization or surgical ligation if it does not resolve. Nonischemic priapism can be summarized as follows:

- Nonacidotic penile blood
- Rare (5% of cases)
- Painless
- Nontender shaft
- Usually traumatic
- Treatment is not time sensitive.

Causes include:

- Trauma
- Arteriocavernosal fistula

Iatrogenic sources are the leading cause of priapism, specifically medications. It is best to quickly review the biochemistry of such (**FIGURE 65.2**). L-arginine is converted to nitric oxide (NO) in the spinal cord via parasympathetic stimulation, secondary to physical or mental stimuli. This NO is then released from terminal nerves of the postganglionic parasympathetic nervous system. NO from these terminal nerves (and also NO release from endothelial cells) directly come in contact with penile erectile tissue. NO diffuses quickly across the cell membrane (half-life is only a few seconds) and activates soluble guanylate cyclase (sGC), which converts guanosine-5'-triphosphate (GTP) into cyclic guanosine monophosphate (cGMP). This induces phosphorylation of ion channels, which decreases intracellular calcium levels, and thus causes smooth muscle relaxation. Smooth muscle relaxation allows arterial dilation, venous constriction, and erection. PDE5 is the predominant phosphodiesterase in the corpus cavernosum and normally degrades cGMP. PDE5 inhibitors, such as sildenafil, potentiate endogenous increases in cGMP by inhibiting its breakdown at the catalytic site. Note that other mediators play a role as well, such as PGE1 (alprostadil is a PGE1 analog), which stimulate adenyl cyclase to increase intracellular levels of cAMP. cAMP has similar effects to lower intracellular calcium as a result of phosphorylation of ion channels.

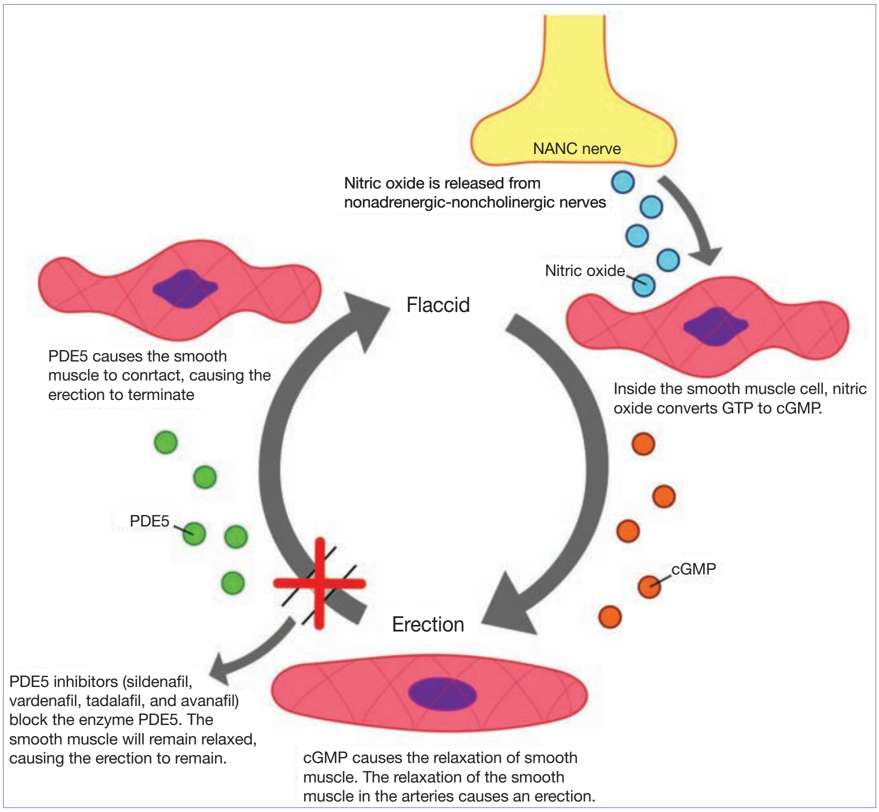

NANC nerve
Nitric oxide is released from nonadrenergic-noncholinergic nerves
Nitric oxide
Flaccid
PDE5 causes the smooth muscle to conrtact, causing the erection to terminate
Inside the smooth muscle cell, nitric oxide converts GTP to cGMP.
PDE5
cGMP
Erection
PDE5 inhibitors (sildenafil, vardenafil, tadalafil, and avanafil) block the enzyme PDE5. The smooth muscle will remain relaxed, causing the erection to remain.
cGMP causes the relaxation of smooth muscle. The relaxation of the smooth muscle in the arteries causes an erection.

FIGURE 65.2 Biochemistry/pharmacology of an erection

cGMP, cyclic guanosine monophosphate; GTP, guanosine-5′-triphosphate; NANC, nonnoradrenergic noncholinergic; PDE5, phosphodiesterase 5.

PATIENT PRESENTATION

Patients with priapism usually present with a very painful, prolonged erection not relieved by ejaculation and not caused by sexual stimulation. As well as a routine physical assessment, the genitourinary examination must include direct visualization of the entire penis. Any signs or symptoms of secondary urinary retention should be quickly ruled out via point-of-care ultrasound (POCUS). The penis is examined, and any areas of necrosis and hematoma are noted. In cases of suspected trauma, note any blood from the urethral meatus. Doppler studies may be performed during examination at bedside via POCUS. Intravenous (IV) access with a bolus of intravenous fluids should be started during triage, or on first assessment. As stated previously, most patients have used vasoactive substances in order to medically achieve an erection. However, in those cases where this is not elicited, one must be cognitive of other etiologies, including many medications not used for ED. Two of the more common medical causes are sickle cell disease and leukemia. In such hematological cases, laboratory studies are warranted, specifically a complete blood count (CBC).

Diagnosis

Medical history taken by the clinician is key to determining the type of priapism. There is no doubt the first objective is to differentiate the diagnosis between the far more common, and emergent, ischemic type and the less common nonischemic variety. Their given treatments are vastly different. Any history of trauma to the penis or perineum, recent or remote, with evidence of sustained erection over 4 hours warrants an evaluation of high-flow priapism. Additional tests used to aid in the diagnosis and management of priapism include:

- Penile Doppler study (**FIGURE 65.3**)
  - Evaluates intracorporeal blood flow in real time
    - Ischemic priapism—**Minimal or absent blood flow** is seen in the cavernosal arteries
      - Thrombosis of the corpora cavernosa or corpus spongiosum
      - Decreased/absent color flow or spectral Doppler in the cavernosal artery/arteries
      - There may still be flow in the superficial penile vein
    - Nonischemic priapism—**Normal to high blood flow** velocities in the cavernosal arteries
  - Chiuo et al. (2009) looked at 52 Doppler studies of the cavernosal arterial flow before and after treatment for priapism and found it is effective in regard to treatment efficacy and termination
  - In the postoperative period of shunt therapy, penile Doppler is important for diagnosing the patency of shunts in doubtful cases.

- A penile cavernous arterial blood gas (ABG) analysis provides direct evaluation of penile blood and serves to provide immediate distinction between the different variants of priapism.
  - Ischemic priapism ABG:
    - Dark, hypoxic, hypercapnic, acidotic
      - pO_2 <30 mmHg, pCO_2 >60 mmHg, pH <7.25
  - Nonischemic priapism ABG:
    - Bright, normoxic, normocapnic, normal pH
      - pO_2 >90 mmHg, pCO_2 <40 mmHg, pH 7.40

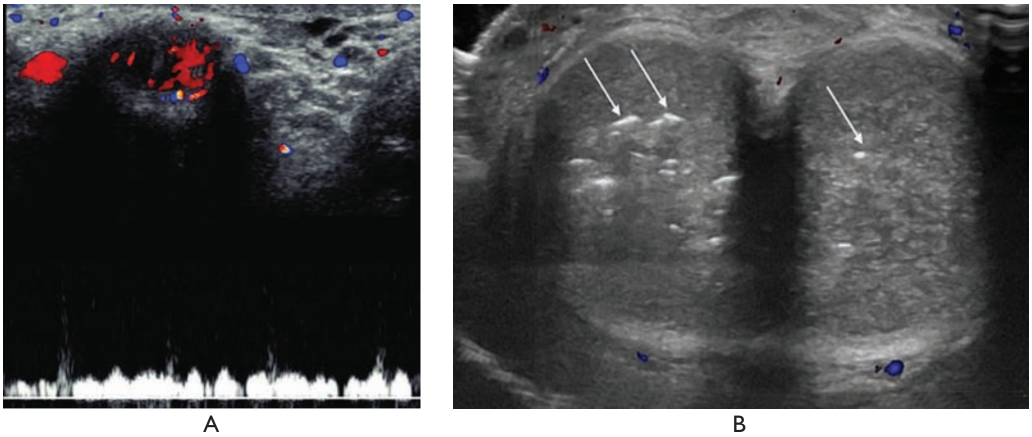

A
B

FIGURE 65.3 (A) Penile Doppler study displaying normal flow at the base of the penis into the corpora cavernosum. (B) Note that there is diminished or absent flow in ischemic priapism.

- MRI (**FIGURE 65.4**)
  - In cases of prolonged ischemic priapism, penile MRI has been shown to accurately assess smooth muscle/corpus cavernosum viability and determine the degree of any fibrosis.
    - Studies have demonstrated a high correlation, with histological analysis and 100% sensitivity, in predicting nonviable smooth muscle.
  - Confirms erectile function restoration.
  - MRI in ischemic priapism demonstrates low signal intensity in the corpus cavernosum and normal high-intensity signal in the corpus spongiosum.
  - There will be no enhancement of the corpora cavernosa on T1- or T2-weighted images postgadolinium administration.
  - Potential benefits of this procedure include its ability to reliably predict nonviable smooth muscle within the corporis cavernosum after episodes of priapism. Drawbacks include the lack of uniform accessibility of MRI, costs, and the time it takes to perform.
    - In 23 cases Ralph et al. (2010) showed that the sensitivity for predicting later erectile dysfunction, via the MRI assessment of smooth muscle viability, was 100%.

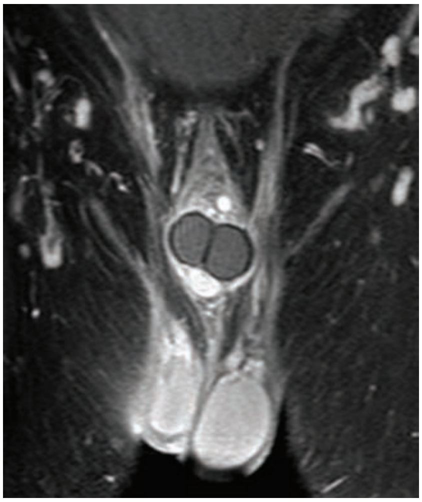


FIGURE 65.4 MRI with gadolinium contrast showing no enhancement of the right and left corpus cavernosum, indicating an ischemic etiology. Note the anterior corpus spongiosum does display enhancement.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Unstable patients
- Hypertensive patients may experience a further increase in blood pressure (BP) with penile injection of alpha-agonist medications.

SPECIAL CONSIDERATIONS

If priapism is due to a hematological disorder, treatment of the particular hematologic disorder is indicated as penile injection may not be solely effective. However, this does not negate penile aspiration and injection therapy. In addition, though rare, urinary retention may result secondary to priapism and a bladder POCUS may be in order.

PROCEDURE PREPARATION

After systemic parenteral analgesia, penile anesthesia may be obtained by either a penile block or local anesthesia. Phenylephrine is considered the treatment medication of choice by the American Urological Association as the consensus is that epinephrine and norepinephrine are not as effective (**FIGURE 65.5**).

- Chlorhexidine or betadine solution
- Gauze sponges and sterile drapes
- 18-gauge needle for aspiration attached to loop tubing
- 30-mL syringes
- 25-gauge needle for injection of phenylephrine
- Phenylephrine syringe diluted with normal saline to a concentration of 100 mcg/mL for a total of 10 1000 mcg/10 mLs.

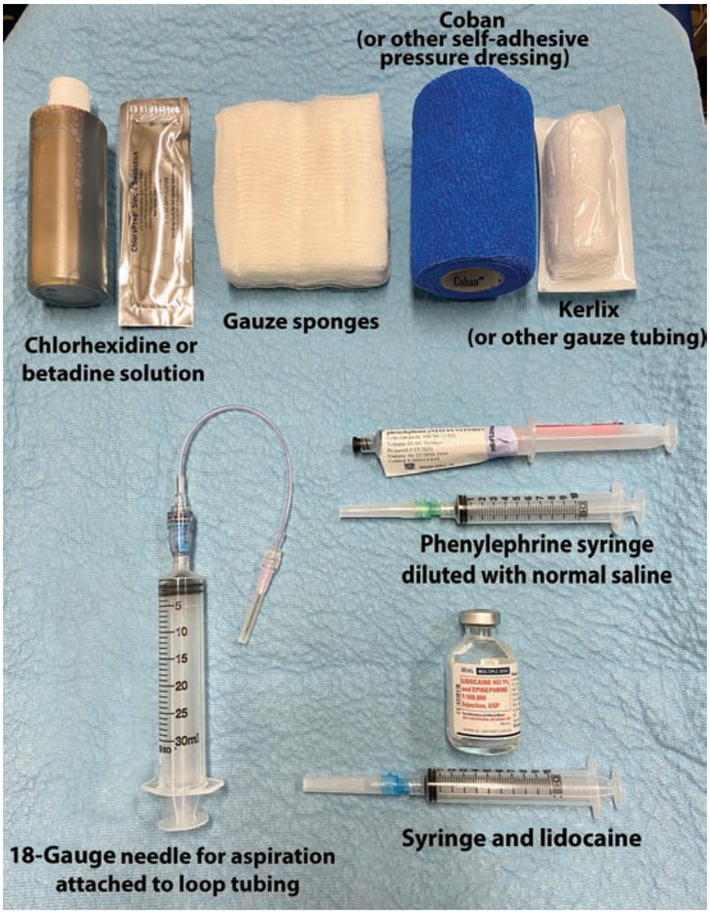
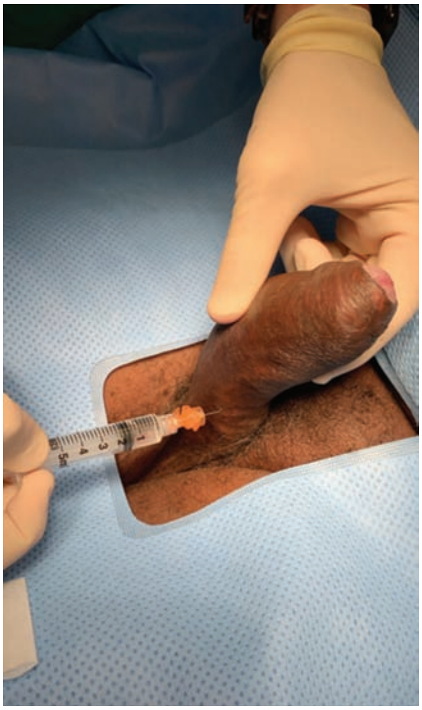

Coban
(or other self-adhesive pressure dressing)
Chlorhexidine or betadine solution
Gauze sponges
Kerlix
(or other gauze tubing)
Phenylephrine syringe diluted with normal saline
Syringe and lidocaine
18-Gauge needle for aspiration attached to loop tubing

FIGURE 65.5 Supplies and setup for analgesia, aspiration, irrigation, and injection.

- Coban or other self-adhesive pressure dressing and Kerlix or other gauze tubing
- Local anesthetic

PROCEDURE

- Patient should be in the supine position (**VIDEO 65.1**).
- Prep the penis by use of a skin cleanser such as chlorhexidine.
- Place sterile drapes around the penis.
- Anesthetize the skin at the area of needle aspiration/irrigation with a local anesthesia. ***All needle entry points must be laterally positioned so as to avoid the anterior urethra and likewise the posteriorly dorsal arteries/veins/nerves*** (**FIGURE 65.6**).
- Using an 18-g needle attached to tubing and syringe, aspirate the dark and congested blood from the corpora. It may be useful to repeat this step on the opposite side (**FIGURE 65.7**).
    - Evacuation of blood by corporal aspiration relieves the compartment syndrome of the penis and serves to counteract local acidotic and anoxic metabolic derangements.
- In addition, upon completion of aspiration, one may instill (irrigate) the corpora with normal saline solution (NSS) in a clean syringe/needle (both similar size) and then repeat aspiration (**FIGURE 65.8**).
- Prepare injection of phenylephrine and inject 1 mL/100 mcg at base of penis every 5 minutes until detumescence is achieved or 1 hour has elapsed (**FIGURE 65.9**).
    - Administration of α-adrenergic agonists is contraindicated in patients who have malignant or poorly controlled hypertension or are concurrently using monoamine oxidase inhibitors.
    - A greater resolution of ischemic priapism is obtained after injection of a sympathomimetic agent with or without irrigation (43%–81%), than after aspiration with or without irrigation alone (24%–36%). Further, the risk of postpriapism ED is lower when sympathomimetic agents are used.
- After resolution occurs, it is helpful to apply firm tube gauze and Coban or other self-adhesive dressing firmly, allowing for the urethra to be free of dressing. This may help with comfort and decrease the risk of an injection-site hematoma.
- If after 1 hour there is no detumescence, urgent consultation with a urologist is mandatory; a surgical shunt may be utilized in the operating room.



VIDEO 65.1 Technique for emergently treating ischemic priapism.

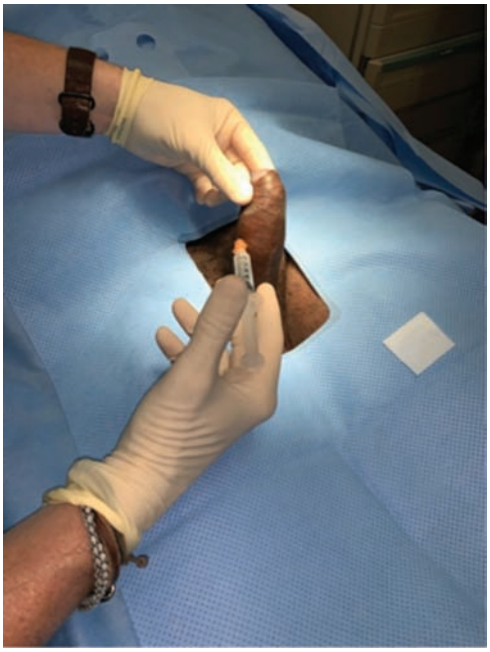


FIGURE 65.6 Local anesthesia subcutaneous injection prior to aspiration/irrigation.

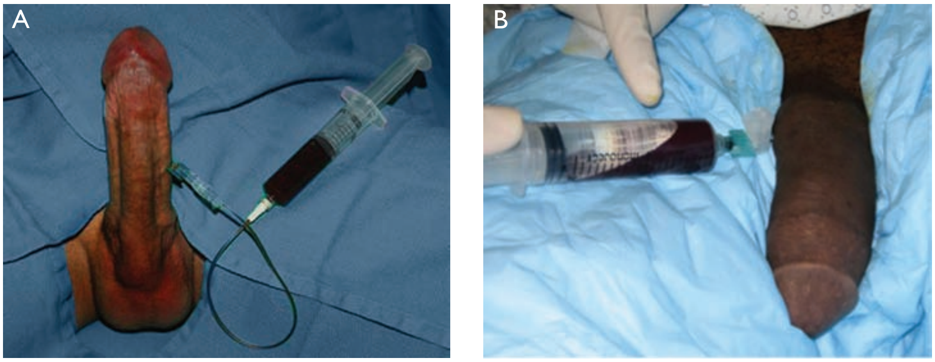


FIGURE 65.7 (A) Aspiration of blood using syringe, loop tubing, and 18-gauge needle. Note the better control obtained and the ability to leave the needle in the corpora. (B) Using the needle syringe method, one must restick the corpora if repeated attempts are necessary.

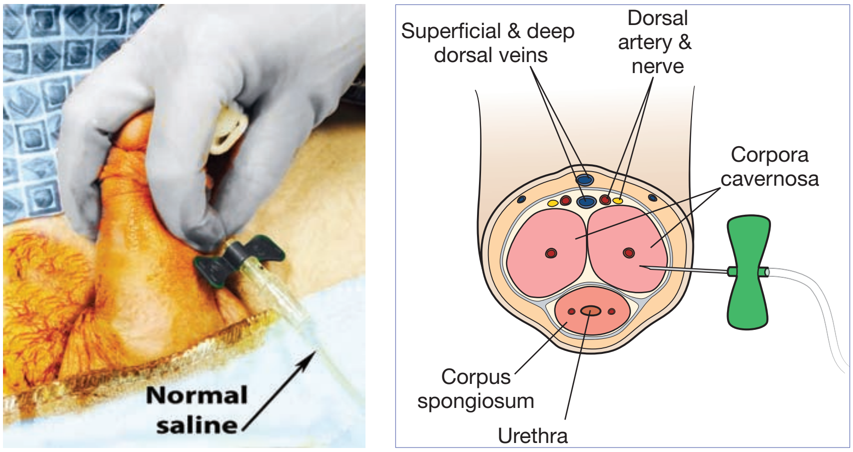

Normal saline
Superficial & deep dorsal veins
Dorsal artery & nerve
Corpora cavernosa
Corpus spongiosum
Urethra

FIGURE 65.8 Irrigation of the corpora using NSS. This step is followed by a repeated step of aspiration.

NSS, normal saline solution.

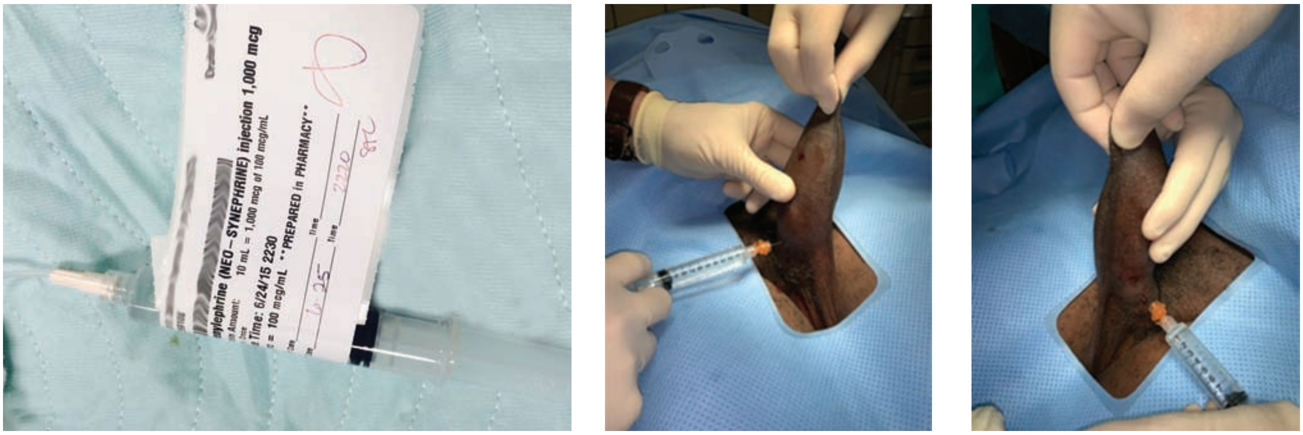
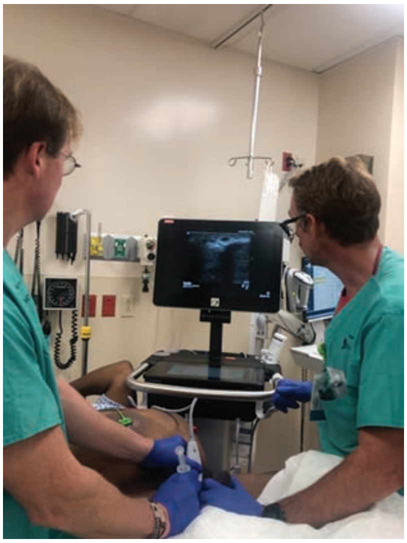

phenylephrine (NEO–SYNEPHRINE) injection 1,000 mcg
10 mL = 1,000 mcg of 100 mcg/mL
Time: 6/24/15 2230
= 100 mcg/mL **PREPARED in PHARMACY**

FIGURE 65.9 Phenylephrine 1,000 mcg/10 mL. Typical preparation of phenylephrine; inject up to 5 mLs (500 mcg) into each corporis cavernosum at the bases with a maximum in aliquots of at least 1 mL (100 mcg) every 5 minutes.

Penile Block

As an alternative to local anesthesia, one may perform an ultrasound-guided penile block (**FIGURE 65.10** and **VIDEO 65.2**).

- With the patient in the supine position, place a high-frequency probe transversely at the base of the dorsal aspect of the penis.
- Note specific landmarks, including the deep dorsal vein, paired dorsal arteries, paired dorsal nerves, and the deep Buck's fascia.
- Under ultrasound guidance, advance a 25- or 27-gauge needle until it is visualized piercing Buck's fascia at the base of the penis and inject 2 to 4 mLs of local anesthesia.
  - Though clinical dogma states never to use a local anesthesia with epinephrine, there is no compelling literature to substantiate such claims.
- Because the needle is between the tunica albuginea (wall of the corpus cavernosum) and Buck's fascia (area of the paired dorsal nerves) and this area is a continuum in loose areolar tissue, both dorsal penile nerves are anesthetized from a single injection; however, both sides can be approached, typically at the 10 and 2 o'clock positions.
- Suleman (2016) also describes an in-plane dorsal penile nerve block approached from a lateral direction using a 27-gauge needle.
- A subcutaneous ring block at the base of the penis in order to anesthetize subcutaneous the penile skin.



VIDEO 65.2 Ultrasound-guided dorsal penile block.

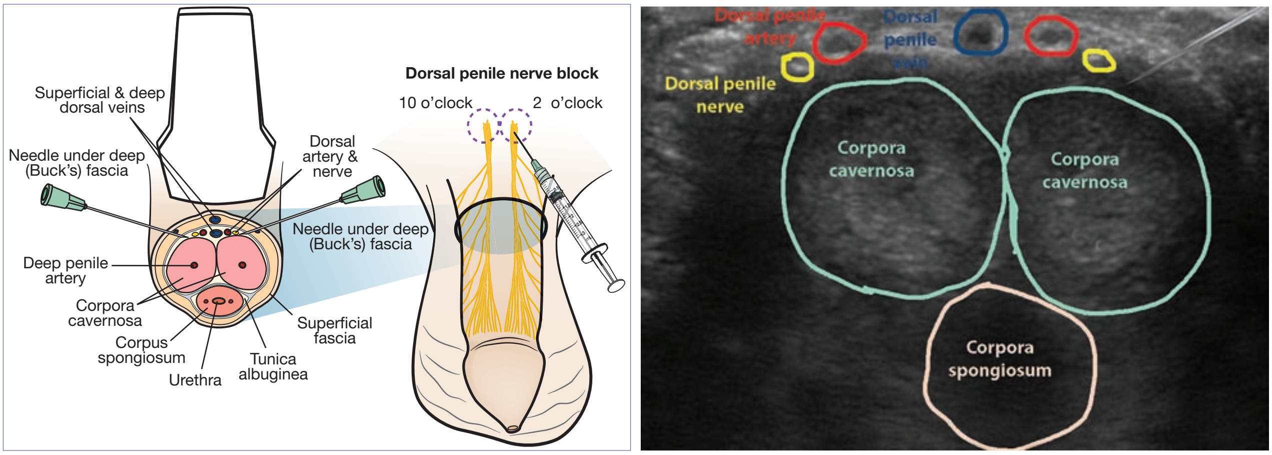

Superficial & deep dorsal veins
Needle under deep (Buck's) fascia
Dorsal artery & nerve
Needle under deep (Buck's) fascia
Deep penile artery
Corpora cavernosa
Corpus spongiosum
Urethra
Tunica albuginea
Superficial fascia
Dorsal penile nerve block
10 o'clock
2 o'clock
Dorsal penile artery
Dorsal penile vein
Dorsal penile nerve
Corpora cavernosa
Corpora cavernosa
Corpora spongiosum

FIGURE 65.10 Dorsal penile block. Note the needle must penetrate Buck's fascia or the local anesthetic will not come into contact with the dorsal nerve.

POSTPROCEDURE CONSIDERATIONS

- Impotence is a feared complication of priapism and rates depend on time-sensitive treatment.
- Postprocedure hematoma is common and generally resolves.
- Patient should be monitored for at least 30 to 60 minutes after the procedure.

EDUCATIONAL POINTS

- In the case of ischemic priapism, immediate penile aspiration should be initiated without delay, irrespective of the cause.
- Ischemic priapism represents a urological emergency; its treatment typically involves aspiration/irrigation coupled with sympathomimetic injections, surgical shunts, and, as a last resort, penile prosthesis implantation.

- Nonischemic priapism results from a continuous flow of arterial blood into the penis, most often related to penile trauma. This is not an emergency and may be managed conservatively initially, as most of these episodes are self-limiting.
- Injection of phenylephrine should be performed immediately after corpus aspiration. To avoid corposal artery injection, the needle should be advanced just until blood is aspirated and no further.
- Counsel as to the necessity of urologic follow-up, avoidance of possible causative agents, and a discussion of the risk of future ED.
- Aspiration of corporal blood with or without saline irrigation has a 30% chance of terminating priapism; however, the literature strongly supports this therapy combined with intercavernosal injection of phenylephrine.
- Oral sympathomimetics (terbutaline, phenylephrine, pseudoephedrine) are superior to placebo if administered within a short time frame (<4 hr) after the onset. This is reported in limited and nonrobust literature as achieving detumescence in 28% to 36% of patients; because of the sequalae of time/tissue death, this should never delay corporal aspiration with or without intracavernosal treatment.

PEARLS

- Systemic analgesia and penile anesthesia are indicated.
- ***Never insert the needle at 12 or 6 o'clock in neurovascular/spongy cavernosum–urethra.***
  - Having an assistant is helpful.
- Treatment must begin immediately upon presentation, as time is tissue.
  - If no treatment occurs within 24 hours, an ED rate of nearly 90% is predicted.
  - Of patients presenting with priapism, 59% will experience ED in the future
- Management of ischemic priapism should progress in an aggressive and stepwise fashion to achieve time-sensitive resolution.
  - Start with aspiration/irrigation of the corpus cavernosum and injection of same with phenylephrine.
- Using the tubing method in lieu of a syringe allows for better control and less discomfort as the needle is more stable.
  - It can be left in place while awaiting resolution between injections, thus decreasing the number of injection sites and pain.
  - Attaching the needle tubing allows for better control of the needle (**FIGURE 65.11**).

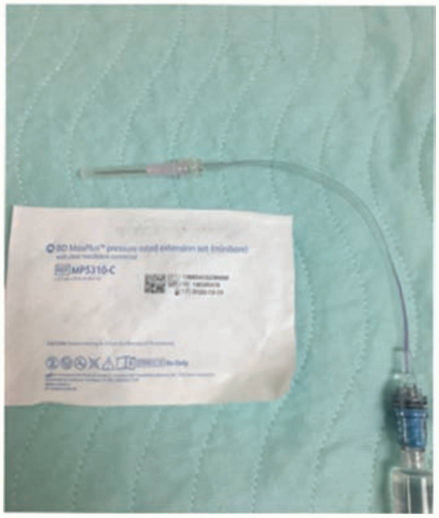


FIGURE 65.11 Needle and tubing attached to syringe.

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CHAPTER

66

Placement and Management of Urinary Bladder Catheters in Adults

M. Bess Raulerson and Lee Ann Boyd

BACKGROUND

Acute presentations of patients requiring urinary drainage are most commonly due to acute urinary retention, obstructed or nonfunctioning indwelling catheters or suprapubic catheters, clot retention, hematuria, and postprocedure complications. In addition, strict monitoring of intake and output in critically ill patients in the ED may warrant utilization of one of the methods of urinary drainage. Patients with spinal cord trauma may experience acute neurogenic bladder resulting in retention and ultimately postrenal azotemia. For this population, it is important to screen for appropriate bladder emptying with ultrasound or bladder scanner as warranted.

Prior to placement of a urethral catheter, a bladder scan or bedside ultrasound is indicated to confirm acute retention, as symptoms of urinary tract infection (UTI), ureterolithiasis, and renal failure may also present with inability to urinate. If the patient has history of ureterolithiasis, a CT of the abdomen and pelvis without contrast should be performed to rule out a urethral stone causing obstruction. In males, imaging may need to extend through the penis to evaluate the distal-most urethra.

A variety of catheters for urinary drainage are available, including external, urethral, and suprapubic catheters. In some patients, placement of a urethral catheter is difficult and multiple attempts are unsuccessful, requiring urgent urological consultation. Most often, males with prostatic enlargement, urethral strictures, or false passages within the urethra result in inability to place a catheter. However, difficult catheter insertion may also be found with postmenopausal females due to vaginal atrophy and the internalization of the urethra with the loss of rugae due to the effect of loss of estrogen on estrogen receptors within the vaginal tissue. Limiting the use of catheters and procedures for bladder emptying to acute and emergent needs decreases the risk of infection, urethral injuries, and discomfort.

PATIENT PRESENTATION

In patients who ultimately require urgent bladder drainage, the most common presentation is acute pain with or without history of recent surgical or urological intervention. Patients may appear diaphoretic, tachypneic, and hypertensive. Acute urinary retention and acute clot retention are more common in males but may occur in females, especially in females who have a history of cancer or recent gynecological surgery. In addition, patients with a history of ureterolithiasis may present with urinary retention due to an obstructing stone in the urethra.

In both males and females, it is imperative to obtain a thorough history and confirm urological conditions prior to insertion of urethral catheters. Patients presenting with acute urinary retention commonly have UTIs and may present with sepsis or septic shock. Further imaging may be indicated in cases of trauma to rule out urethral injury, bladder injury, or bladder rupture.

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

Acute Urinary Retention

Urinary retention may result from obstructive, infectious, neurologic, and/or pharmacologic etiologies (**TABLE 66.1**). Multifactorial etiologies are frequently encountered in the emergency care setting.

In addition to the medications listed in **TABLE 66.1**, common medications causing urinary retention include the following:

- Opioids and anesthetics
- Alpha-adrenoreceptor agonists
- Benzodiazepines
- Nonsteroidal anti-inflammatory drugs (NSAIDs)
- Detrusor relaxants
- Calcium channel antagonists

Obstructive Urinary Retention

Patients with benign prostatic hypertrophy (BPH) may have long-standing lower urinary tract symptoms ("LUTS") or may not realize that they have any issues until they are suddenly unable to void. The process of prostate enlargement can produce gradual symptoms, including frequency, feelings of incomplete emptying, nocturia, and urgency. Some patients may experience dysuria with a sense of needing to push to void or empty. Patients with gradually increasing symptoms may suddenly develop acute urinary retention due to medication, recent anesthesia, constipation, or recent abdominal or pelvic surgery.

TABLE 66.1 **Four Categories of Urinary Retention Causes: Obstructive, Infectious, Neurologic, and Pharmacologic**

	Obstructive	Infectious
Male	■ Benign prostatic hypertrophy ■ Meatal stenosis ■ Paraphimosis ■ Prostate cancer	■ Balanitis ■ Balanoposthitis ■ Prostatic abscess ■ Prostatitis
Female	■ Gravid uterus ■ Organ prolapse ■ Pelvic mass	■ Vulvovaginitis
Male or female	■ Bladder calculi ■ Bladder neoplasm ■ Edema ■ Fecal impaction ■ Malignancy ■ Pelvic/urogenital trauma ■ Urethral stenosis	■ Cystitis ■ Herpes simplex viral infection ■ Varicella zoster viral infection ■ Lyme
	Neurologic	
Autonomic/peripheral	■ Diabetes mellitus ■ Guillain-Barré syndrome ■ Tabes dorsalis	
Brain	■ Cerebrovascular accident ■ Multiple sclerosis ■ Multiple system atrophy (formerly known as *Shy-Drager normal pressure hydrocephalus*	
Spinal cord	■ Cauda equina ■ Multiple sclerosis ■ Spinal epidural abscess ■ Spinal stenosis ■ Trauma	
	Pharmacologic	
Class	■ Anticholinergics ■ Antidepressants ■ Antihistamines ■ Antipsychotics	

Prostatic enlargement results in difficulty passing a catheter into the bladder due to constriction of the urethra by the enlarged tissue (**FIGURE 66.1**). The prostatic urethra, the portion of the urethra that passes through the prostate, may be completely blocked or portions may be narrowed secondary to excessive alpha-adrenergic tone in the prostate gland (**FIGURE 66.2** demonstrates prostate anatomy) obstruction. The entire prostate gland does not have to be enlarged to cause obstruction. Other causes of obstruction include prostate cancer, phimosis, paraphimosis (see Chapter 64, Procedures for Treating Phimosis and Paraphimosis), external constricting devices applied to penis, urethral stricture, and false passages in patients who self-catheterize (**FIGURE 66.3**).

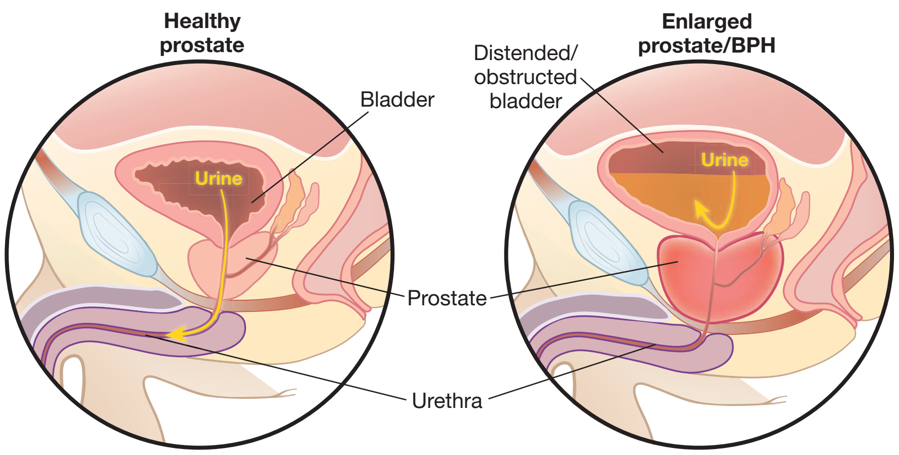

Healthy prostate
Enlarged prostate/BPH
Bladder
Distended/ obstructed bladder
Urine
Urine
Prostate
Urethra

FIGURE 66.1 Prostatic enlargement that can cause difficulty passing a catheter. BPH, benign prostatic hyperplasia.

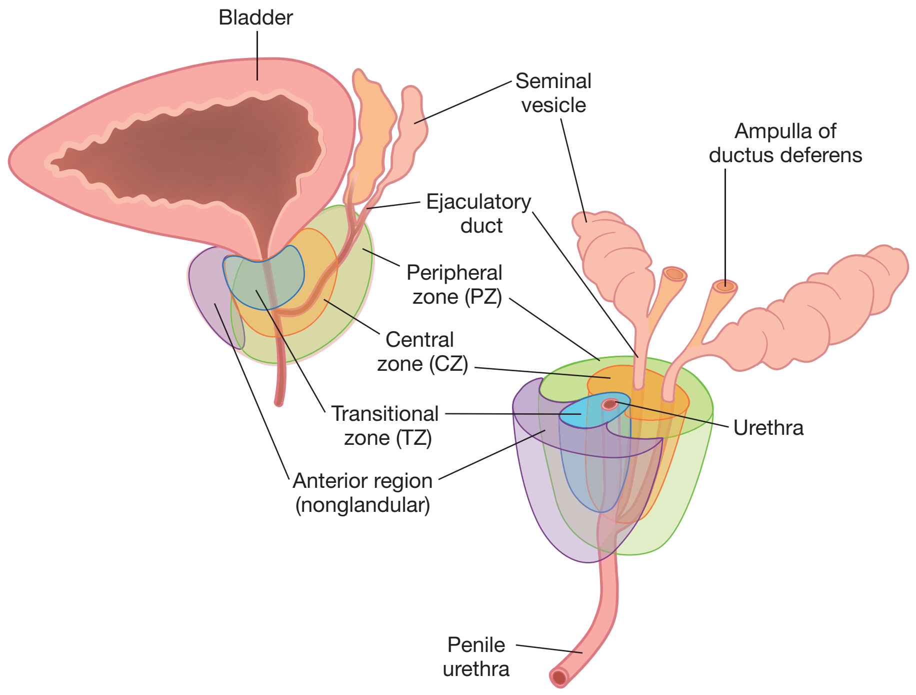

Bladder
Seminal vesicle
Ampulla of ductus deferens
Ejaculatory duct
Peripheral zone (PZ)
Central zone (CZ)
Transitional zone (TZ)
Urethra
Anterior region (nonglandular)
Penile urethra

FIGURE 66.2 Prostate anatomy and different zones that may cause obstruction of urethra due to enlargement in distinct zones without diffuse enlargement.

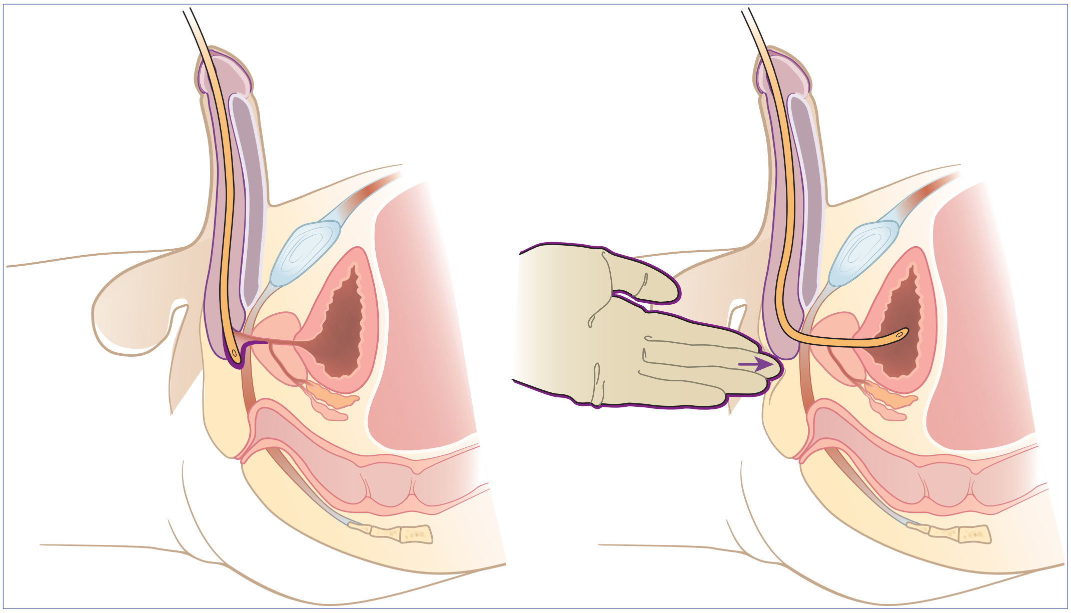


FIGURE 66.3 Urethral angulation, false-passage production, and perineal pressure at time of catheter insertion to avoid creation of false passage at site of bulbar and prostatic urethra.

Infectious Urinary Retention

In men, infectious urinary retention is most common secondary to acute prostatitis (**FIGURE 66.4**) but may also occur with urethritis due to other sexually transmitted infections (STIs) or UTIs resulting in urethral edema. In addition, genital herpes may cause local inflammation and sacral nerve inflammation resulting in poor bladder function. In women, vulvovaginal lesions and vaginitis may cause urethral edema, resulting in acute retention.

Clot Retention and Hematuria

Patients presenting with clot retention usually report a history of hematuria that is initially painless, followed by gradually dwindling or sudden cessation of urinary output. This is accompanied by gradual onset of suprapubic pain that rapidly becomes severe and is commonly associated with lower abdominal distention. In these patients, infection and

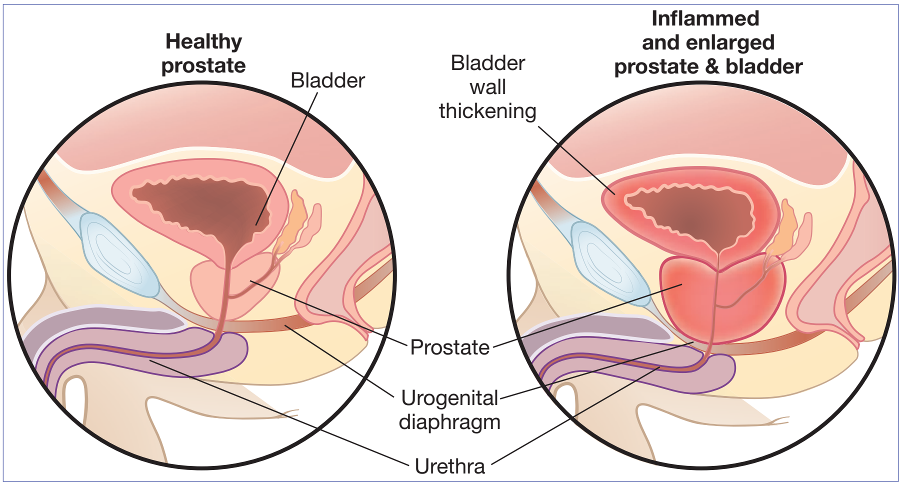


FIGURE 66.4 Enlarged prostate due to infection, resulting in acute prostatitis.

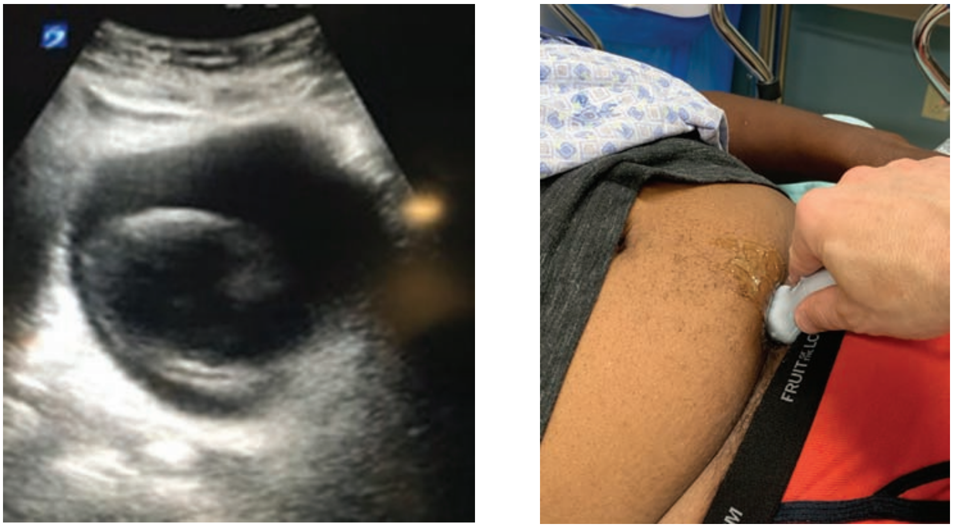


FIGURE 66.5 Point-of-care ultrasound of bladder in patient with acute clot retention. Pictured is a distended bladder with an organized clot requiring placement of a hematuria catheter and bladder irrigation.

hematuria often preceded the retention, but bladder cancer in women and recent bladder or urethral procedures may also contribute.

Point-of-care ultrasound (POCUS) can be utilized to identify a clot as the cause of obstructive retention. **FIGURE 66.5** demonstrates a dilated bladder from clot formation and **FIGURE 66.6** demonstrates clearance of the clot with a return to normal-size bladder postirrigation and clot removal.

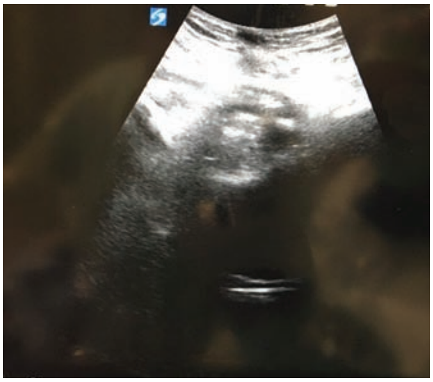


FIGURE 66.6 Point-of-care ultrasound of bladder after manual irrigation demonstrating clearance of consolidated clot with 30-mL balloon inflated and noted in bladder.

POSTPROCEDURE COMPLICATIONS

In the case of a recent urological procedure resulting in acute retention, consultation with a patient's urologist is indicated prior to instrumentation of any kind to confirm optimal treatment.

TREATMENT

Once the need for acute urinary drainage is identified, an indwelling urinary catheter (**FIGURE 66.7**) will most likely be utilized to prevent renal injury by eliminating postrenal azotemia and improving urinary output. Examples of types of urinary catheters vary; the most common types are pictured in **FIGURE 66.8**.

Patients reporting a history of hematuria with urinary retention, especially if they have had recent urological intervention or history of blood thinner therapy, may need specialized catheter placement with a three-way urinary catheter to allow for bladder irrigation and clot removal.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Pelvic or genital trauma should prompt evaluation for urethral injury before catheter placement. A urologist should be consulted if there is high suspicion for urethral injury.
- Patients with recent urological intervention and indwelling catheter malfunction or displacement require consultation with a urologist prior to instrumentation.
- In latex-allergic patients, opt for a silicone catheter.
- In cases of hematuria and clot retention, opt for a specialized hematuria catheter or three-way catheter if hematuria catheter is not available.

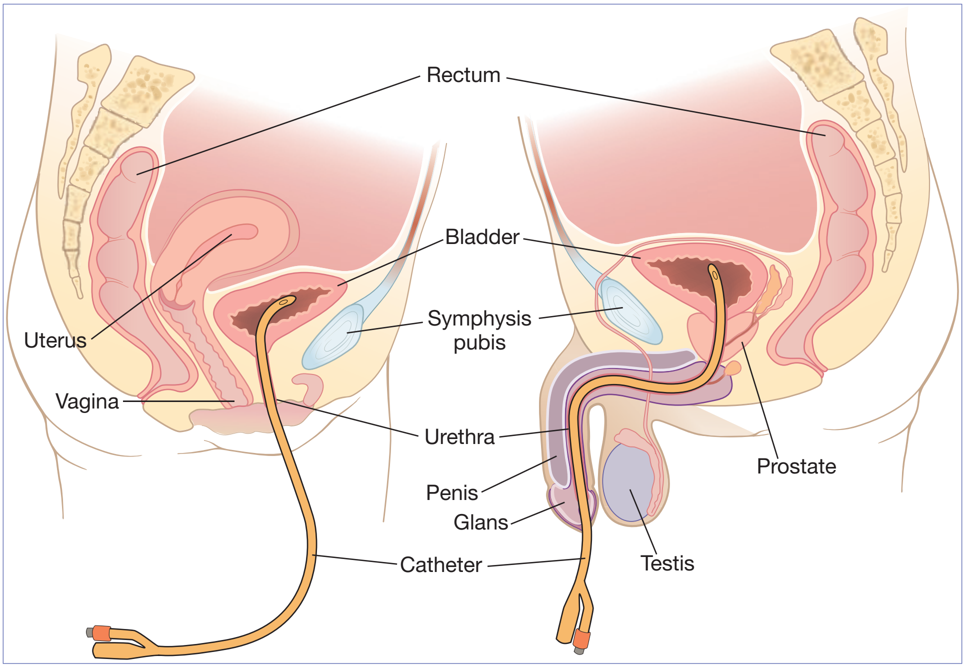


FIGURE 66.7 Indwelling urinary catheters in female and male patients.

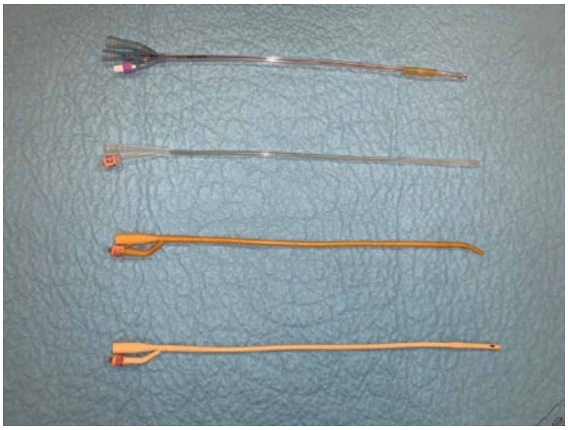


FIGURE 66.8 Types of urethral catheters from top to bottom: Rusch hematuria catheter, silicone latex-free catheter, Coude catheter, straight-tip catheter. *Note*: These are not all hematuria catheters.

SPECIAL CONSIDERATIONS

In most cases, urethral catheterization can be accomplished easily. However, in cases in which the prostate is very enlarged, specialized maneuvers, equipment, and procedures will increase successful, nontraumatic passage of urethral catheters. It is vitally important that the catheter is never "forced"; when encountering resistance, it is better to adjust the procedure and equipment to avoid trauma to the urethra and prostate. Most often, multiple attempts at placement of the catheter result in a false passage. Ninety percent of false passages occur because the catheter tip perforates the posterior urethral wall instead of moving up to the prostatic lumen (**see FIGURE 66.3**). A combination of sphincter contraction and change of direction (urethral angle) make this point a crucial place of urethral passing. To reduce this angle, using a mild but firm traction over the penis with one hand (pulling up and toward patient's head) while introducing the catheter with the other may reduce the angle enough to allow passage of the catheter. Also, using a Coude catheter can improve the chances of success in men with enlarged prostates. Applying gentle pressure to the perineum and guiding the catheter with a second hand provided by an assistant can help avoid false passage (**see FIGURE 66.3**).

Selection of appropriate equipment, providing preprocedural medication, and patient comfort can contribute to the ultimate success or failure of urethral catheter placement. Providing preprocedure medication in patients with severe pain and distress due to retention can decrease intraabdominal pressure. Selecting the most appropriate catheter based on etiology of presentation will most effectively treat the underlying cause and minimize difficulty visualizing the female urinary meatus. Examples of appropriate catheters to address the underlying issue are choosing a Coude Foley catheter in cases of suspected or confirmed BPH, a commercial hematuria catheter in cases of suspected or confirmed clot retention, or a silicone catheter in cases of latex allergy (**see FIGURE 66.8**).

Bladder Clot Retention and Hematuria

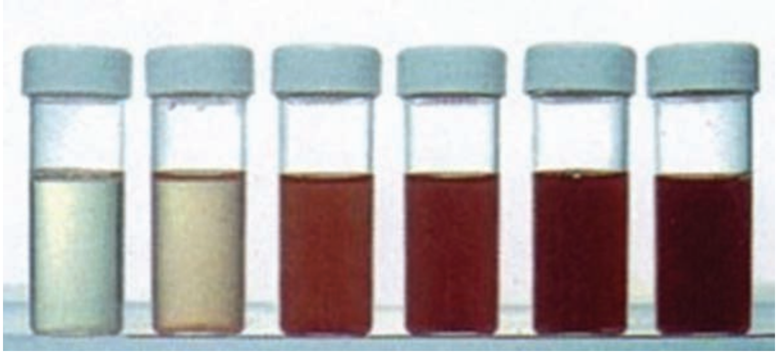


FIGURE 66.9 Degrees of hematuria from microscopic to grossly bloody.

It is important to note that simply having hematuria is not an indication for urethral catheterization unless the patient also has retention. However, if urine is grossly bloody, a catheter may be indicated for continuous bladder irrigation (CBI). For patients presenting with hematuria and complaints of urinary retention, it is important to determine the degree of hematuria in order to choose the appropriate equipment (**see FIGURE 66.8**). If the clinician is able to see through the urine, regardless of the color, then the urine is not grossly bloody. Urine described as ketchup or barbecue sauce that is thick in consistency requires CBI. **FIGURE 66.9** demonstrates various degrees of hematuria. Selection of a three-way catheter for irrigation is mandatory and selection of the commercial hematuria catheter is strongly suggested. The commercial hematuria catheter has very large drainage holes at the tip of the catheter, which allows small clots to pass without obstructing the catheter. It is made from silicone, thereby preventing collapse, and easily allows for better irrigation of the bladder, clearing the urine so the degree of hematuria can easily be seen.

Hematuria can be a sign of a variety of urological complications, including cancers, infection, kidney disease, vasculitis, and trauma. In patients with gross hematuria who did not recently undergo urological procedures, imaging or urological evaluation may require upper tract imaging, with and without contrast or CT urogram. In the emergency, urgent care, and primary care settings, a noncontrast study may be sufficient to rule out stones and pathology as long as urological follow-up is secured for further evaluation. In patients with hematuria and retention due to clot retention or other blockage in the bladder and urethra, placement of a large-bore, 20- to 24-French, three-way commercial hematuria catheter for urgent evacuation of clots via manual irrigation is indicated. The blood clots within the bladder break down due to urinary urokinase, which activates the fibrin fragments that act as natural anticoagulants, resulting in the bleeding continuing and making the controlling of the bleeding difficult. If a patient is placed directly on CBI without first performing manual irrigation of all the clots from the bladder, there is a risk of bladder perforation, renal failure, and acute anemia due to blood loss.

In extreme cases, bladder perforation can occur when clots block the catheter. The CBI irrigation fluid continues to flow, filling the bladder rapidly and beyond the normal stretching capacity of the bladder, resulting in perforation. Often, patients experience worsening pain, and fluid is noted to leak around the catheter. In all cases the catheter that is leaking needs to be repositioned and irrigated by hand to remove any clots.

PROCEDURE PREPARATION

- Sterile urethral catheterization kit/tray (includes cleaning and preparation supplies, sterile lubrication, and sterile towels as well as drainage bag and tubing)
- Catheter of choice
- Sterile 2% lidocaine jelly
- Sterile water to fill balloon
- Two prefilled sterile 5-mL flushes
- Sterile gloves and clean gloves
- Appropriate catheter
- Utilize appropriate personal protective equipment during entire procedure and maintain sterile technique
- Using clean gloves, cleanse urethral meatus and glans of penis or labia with cleaning solution provided in catheterization kit
- Discard clean gloves and don sterile gloves
- Drape perineum and abdomen with drapes provided in catheterization kit so only penis or perineum exposed

PROCEDURE

Urethral Catheterization

MALE CATHETERIZATION PROCEDURE

- If using lidocaine, instill into urethra and hold tip of urethra closed for 3 to 4 minutes (this step can be performed by assistant after cleansing of penis while supplies are set up).
- Grasp penis at base with nondominant hand and grasp catheter with dominant hand.
  - If using a Coude catheter, note that tip of the curved end of the catheter is at 12 o'clock and note position of the hub. Keep the hub steady as you direct the catheter proximally to keep the tip always pointing up at 12:00.
- Lubricate the tip of the catheter generously.
- Advance the catheter into the urethra while holding the penis in the nondominant hand and, as you advance, gently lift and gently pull the penis at the same time.
  - If you feel resistance, lift the penis more toward the patient's head and pull slightly more firmly as you gently push the catheter toward the bladder.
    - Tip: As you pull and lift the penis toward the patient's head, attempt to advance the catheter gently. If meeting resistance, pull back the catheter slightly and pull up on the penis again in stepwise fashion, approximately an inch or so at a time, and with each position change attempt to advance the catheter so that you are pulling up with one hand and pushing forward with the other, attempting to "find the opening."
    - Have an assistant apply pressure to the perineum as pictured in **FIGURE 66.3** to avoid causing a false passage and to help direct the catheter into the bladder.
    - By pulling the penis, you are "flattening" the urethra and helping to direct the tip of the catheter to the prostatic urethra.
- Continue to advance until a "Y"-shaped hub is at the tip of the penis. Do not stop advancing when you see urine; full advancement into the bladder must be completed prior to filling the balloon to avoid urethral, prostatic, and bladder neck damage.
- Fill the catheter balloon with sterile water only to its capacity, noted on the packaging (10–30 mL on average). Use of normal saline can break down a latex balloon.
  - If there is minimal or no urine and the catheter is fully inserted, do not fill the balloon until you have verification of placement of the catheter by using the two 5-mL NaCl flushes.
    - Insert the hub of the sterile flush into the drainage port of the catheter and instill fluid, then pinch the end of the catheter hub to keep from leaking and insert a second flush into the catheter and, keeping the syringe in place, pull back on the plunger. NaCl should freely flush out of the bladder through the catheter. If there is any resistance, remove or reposition the catheter as it may be in a false passage, coiled at the prostate, or kinked.
- Connect the catheter to the drainage bag of choice (leg bag for planned discharge).
  - Securing the catheter to the patient's leg via locking device can cause damage to the urethra if not performed appropriately.
    - Most hospitals require this device, but an order can be placed to override it.
    - If the catheter is secured to a locking device on the leg and the patient moves the leg, then the balloon can be pulled down into the urethra and cause catheter obstruction, hematuria, urethral damage, scar tissue, and pain.
  - If the patient is awake, ambulatory, and oriented and being admitted to the hospital, consider an order to not place the catheter locking device.
  - If the patient is disoriented or at risk for delirium, place a locking device as high up on the leg as possible while still allowing for slack.
  - Do not send patients home with a locking device on the leg.

FEMALE CATHETERIZATION PROCEDURE

- Position the patient's legs widely apart and have an assistant help to separate the labia and attempt to visualize the urethra.
- Using the dominant hand, grasp the appropriate catheter and generously lubricate.
- Insert the tip of the catheter into the urethra and advance as described previously.
  - In females with vaginal atrophy, the vaginal opening is greatly diminished, and the urethral meatus is internalized and may not be visible (**FIGURE 66.10**).
    - In severe cases, anatomical landmarks are very difficult to distinguish.
    - In some patients, due to limitations in mobility (e.g., hip fracture), anatomical landmarks cannot be visualized due to patient positioning issues and tolerance.

- In this case, the lubricated, sterile nondominant index finger can be inserted into the vagina with the hand in the supine position and the anterior wall of the vagina gently palpated.
    - Palpate for a "bump" toward the opening but behind the clitoris as this is the urethral opening and hold the finger gently behind it.
        - Tip: Use of a 12- to 14-French silicone catheter is especially useful for this scenario as it maintains its stiffness and can be easily directed without collapse.
    - Slowly advance the catheter toward the internal finger, maintaining the finger in place and guide the catheter up the finger and into the urethra.
- Confirm urinary return before filling the balloon and attach the catheter to the drainage bag.

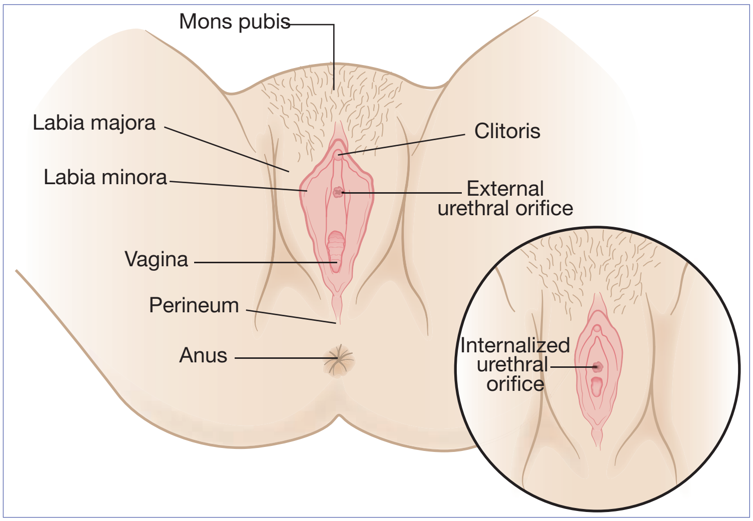


FIGURE 66.10 Vaginal anatomy and vaginal anatomy with severe vaginal atrophy (*inset*).

Special consideration should be given to older women with severe vaginal atrophy as even a lubricated finger may cause trauma or tears and catheter insertion may have to be avoided.

MANUAL BLADDER IRRIGATION (MALE OR FEMALE) (VIDEO 66.1)

- First, assemble appropriate equipment and utilize an assistant for the entire procedure (**FIGURES 66.11**, **66.12**, and **66.13**).
- Place three-way, large-bore (20–24 French), preferably commercial hematuria catheter and place the catheter plug in the irrigation port (**see FIGURES 66.11** and **66.12**).
    - Be certain the catheter is in the bladder by irrigating and inserting to the hub (**see FIGURE 66.14**) and noting no resistance before filling the balloon.
        - Tip: Most three-way catheters have 30-mL balloon reservoirs. Begin the irrigation procedure with only 10 mL in the balloon initially as the larger balloon can trap clots between it and the bladder wall (**FIGURE 66.15**).

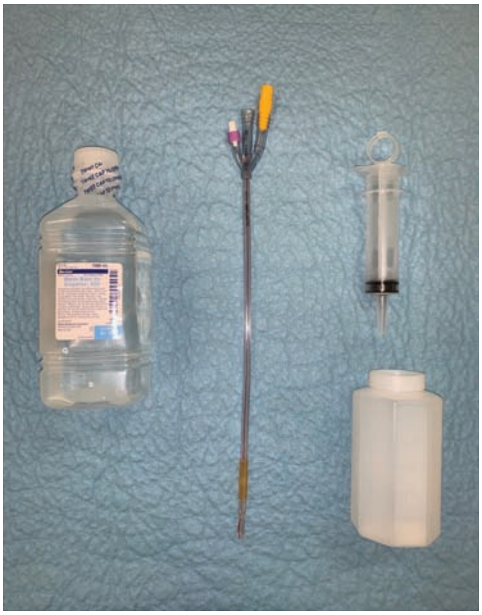


FIGURE 66.11 Setup for manual irrigation of the bladder: sterile water, commercial hematuria catheter with catheter cap located in irrigation port to block it, Toomey syringe, and container for irrigation solution. Note the balloon hub is pink, the main port is in the middle, and the irrigation port (only for CBI irrigation) has a yellow plug.

CBI, continuous bladder irrigation.

VIDEO 66.1 Bladder irrigation.

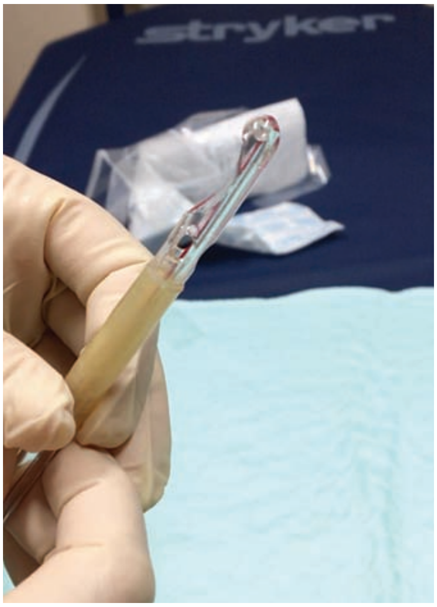


FIGURE 66.12 Rusch hematuria catheter. Note large hole at the tip for passage of clots.

- Fill a Toomey syringe with sterile water (NaCl can also be used but sterile water is better for lysis of clots—see **FIGURE 66.16**) and insert the fluid into the main catheter port (be sure the catheter plug is in place in the irrigation port) and very, very firmly push water into the bladder (**FIGURE 66.17**).
  - You are attempting to "pressure wash" the bladder (**FIGURE 66.18**) to break up and lyse clots and pull them out via the catheter.
  - Tip: Be sure you have a firm connection and hold onto the syringe and catheter to avoid being sprayed with blood and urine (**see FIGURE 66.19**).
- After pushing fluid into the bladder, keep the syringe in place, pull back on the plunger, and withdraw clots and hematuria (**FIGURE 66.20**).
- Continue flushing the bladder manually until no further clots are noted and urine appears light pink or "watermelon pink" (**FIGURE 66.21**).
  - Tip: Rotate the catheter intermittently to try to wash all areas of the bladder.
- Once there are no further clots and urine is light pink, attach the catheter tubing to the main middle drainage port, remove the catheter plug, and attach irrigation tubing (**FIGURE 66.22**).
- Attach the catheter to CBI and irrigate the bladder continuously with 3,000 mL of NaCl to flush out any remaining clots or debris (**FIGURE 66.23**) and then continue CBI as needed, titrating down flow as needed to keep urine clear to light pink. Note that this procedure is very time-consuming for the staff caring for the patient as the bag will need to be changed frequently.

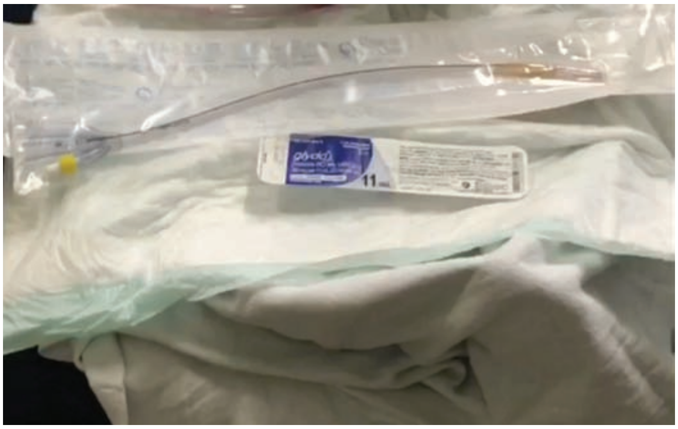


FIGURE 66.13 Choosing the appropriate equipment before the procedure begins is critical for success.

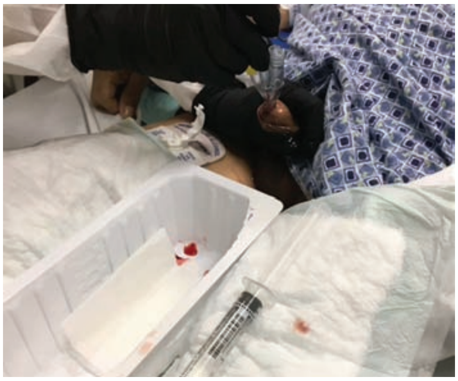


FIGURE 66.14 Insert the catheter to the hub in order to ensure its position fully in the bladder before inflating the balloon; this avoids a urethral balloon inflation.

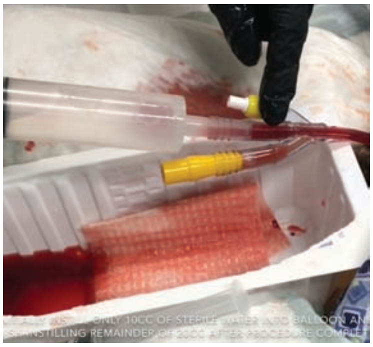

ONLY 10CC OF STERILE WATER INTO BALLOON AN
INSTILLING REMAINDER OF 20CC AFTER PROCEDURE COMPLET

FIGURE 66.15 Balloon port. Initially, only instill 10 mL of sterile water into the balloon port. Upon completion of the procedure, instill the remaining 20 mL for a total of 30 mL.

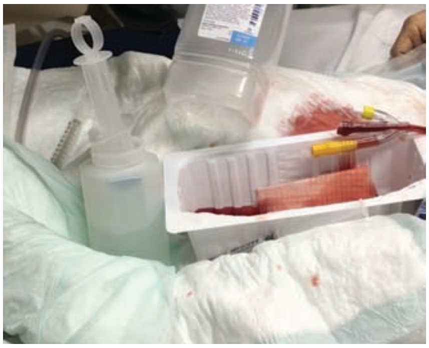


FIGURE 66.16 Sterile water lysis. Use sterile water for manual irrigation as the hypotonicity induces greater clot lysis. Have an assistant refill the irrigation solution.

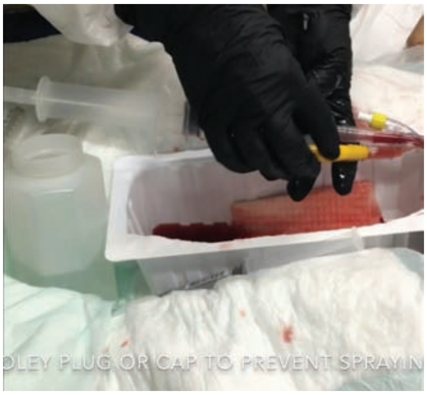


FIGURE 66.17 Ensure the use of a Foley plug/cap in order to prevent splattering.

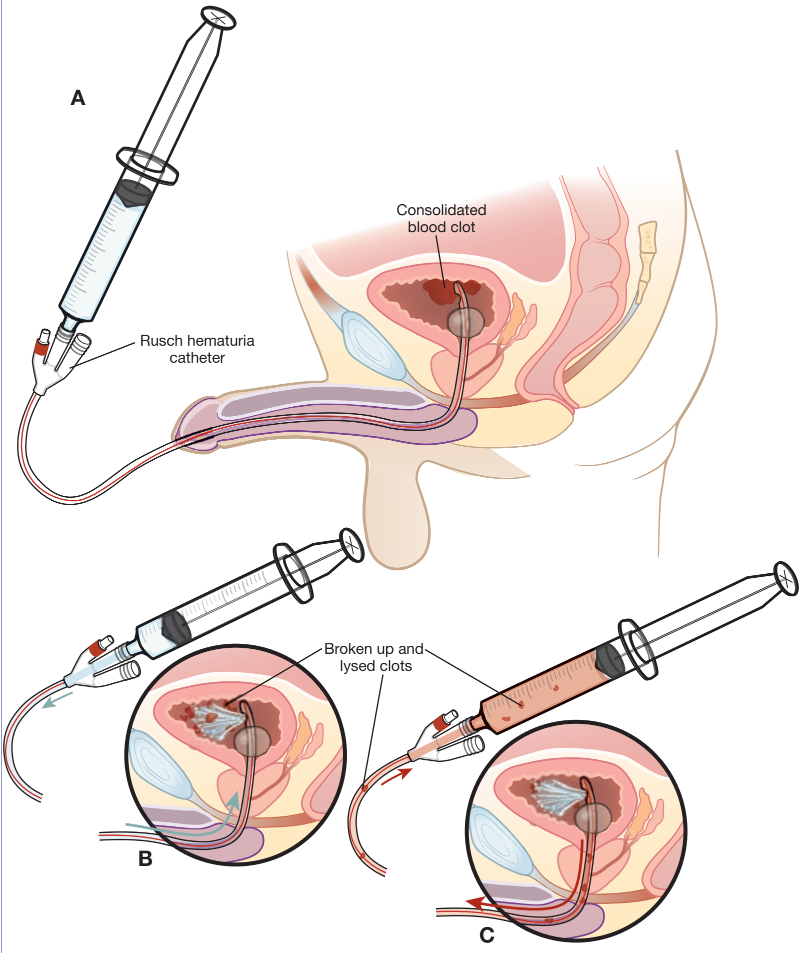

A
Consolidated blood clot
Rusch hematuria catheter
Broken up and lysed clots
B
C

FIGURE 66.18 Demonstrating the "pressure cleaning" to flush out and lyse clots from the bladder. Pictured is a commercial hematuria catheter and Toomey syringe utilizing firm pressure to push sterile water, which helps to lyse clots to allow them to pass through the catheter without obstructing the catheter.

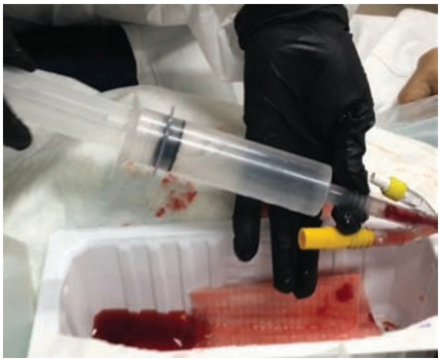


FIGURE 66.19 Securely grasp the catheter tip/hub in order to ensure security.

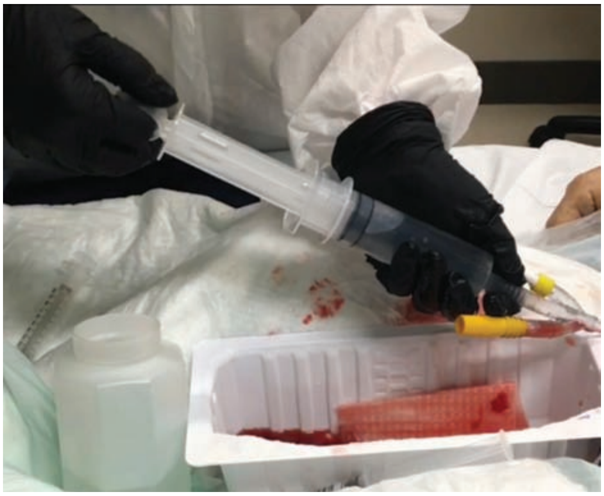


FIGURE 66.20 Generous and steady pressure is required not only to shatter but also to aspirate clots.

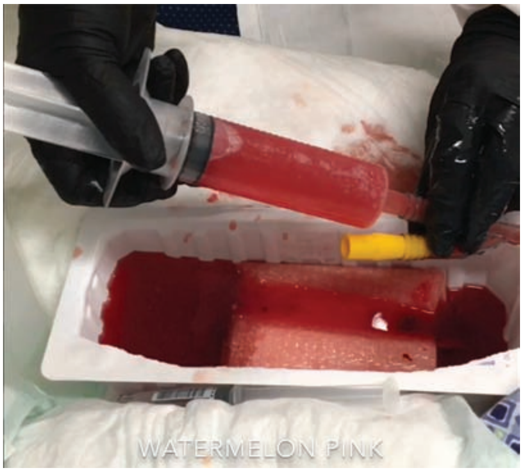

WATERMELON PINK

FIGURE 66.21 The clinician must continue with manual irrigation until both of the following have occurred: clot aspiration has ceased and the urine transforms into a pink/watermelon color.

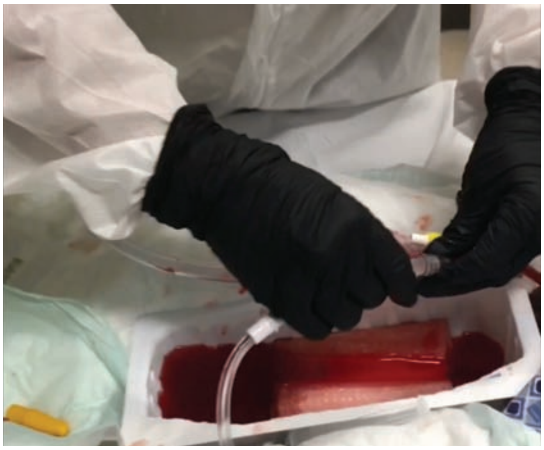


FIGURE 66.22 Continuous bladder irrigation attachment. Remove the catheter plug, attach the CBI tubing to the lateral irrigation port, and attach the drainage bag tubing to the middle drainage port.

CBI, continuous bladder irrigation.

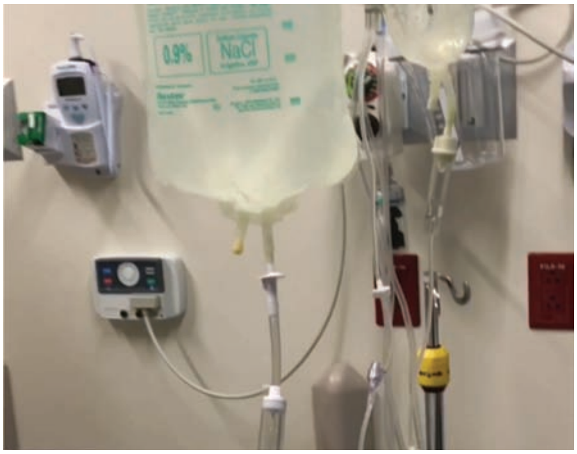


FIGURE 66.23 Three liters of CBI solution run wide open to further flush out any remaining clots.

CBI, continuous bladder irrigation.

POSTPROCEDURE CONSIDERATIONS

- Prophylactic antibiotics are not recommended after placement of a urinary catheter unless placement resulted in trauma or multiple attempts. If antibiotics are warranted, then one dose of intravenous (IV) ceftriaxone, piperacillin, tazobactam, or levofloxacin is recommended.
- Antibiotics are indicated in every case of manual bladder irrigation as the procedure can be traumatic. Despite performing under sterile technique, the invasive nature of the procedure can result in infection. As indicated previously, one dose is recommended and should be given prior to or just after the procedure.
- Run the first 3,000-mL solution bag of NaCl wide open to flush out any remaining clots or residue (**see FIGURE 66.23**). As the clots should no longer be retained, NaCl is preferred as it is less irritating to the bladder. With the second bag of NaCl, titrate the drip rate to keep the urine clear to very light pink. If it gets redder, increase the drip rate; as it gets clearer, decrease the drip rate.
- Once CBI has been started, intermittent clogging of the catheter may occur and require sporadic manual irrigation. This most often occurs because the drip rate is too low and clots form.
  - If the catheter is leaking and/or patient is having increased pain, the catheter has clotted off and manual irrigation must be performed to clear all clots before restarting CBI.
  - It is imperative that the drip rate be high enough to keep the urine clear to light pink.

EDUCATIONAL POINTS

- If the patient is to be discharged with a catheter, educate the patient to keep the leg bag above the knee to avoid putting tension on the catheter.
- If the catheter is not draining, patients should return for evaluation or follow-up with the urologist.
- Small amounts of blood may be normal but if urine becomes bright red instruct the patient to return for reevaluation or follow-up with the urologist.
- Most patients who have required bladder irrigation require admission for CBI. In some cases, however, appropriate patients, after being trained how to manually irrigate the catheter, may be discharged to home with manual irrigation equipment once a clogged catheter is flowing appropriately, after consultation with the urologist and follow-up are established.
- Patients may shower with the catheter in place but should not submerge it in water.
- A catheter securing device should be placed on patients who are bedridden or have altered mentation. Care must be taken to ensure there is slack in the tubing to avoid trauma.

COMPLICATIONS

- Infection is the most common complication of both insertion of the catheter and irrigation of the catheter.
- Bladder rupture is an uncommon complication of bladder irrigation but can occur if blood clots obstruct the catheter and the bladder fills rapidly. Pain can be very severe prior to rupture and should be an indicator of impending rupture.
- Urethral trauma and false passages may occur with placement of the catheter.
- Catheter can be displaced or clogged with debris or blood and require repositioning or replacement.

PEARLS

- If passing a catheter fails after multiple attempts, consideration can be given to use of a Sensor Guidewire into the catheter prior to placing it into the urethra (**FIGURES 66.24**, **66.25**, and **66.26**). This helps to avoid curling up of the catheter against resistance. It is important to have an assistant hold onto the end of the wire that is outside of the catheter and to ensure the soft Sensor wire tip is at the end of the catheter but within the catheter lumen and visible through holes in the tip of the Foley (**FIGURE 66.27**). The guidewire at the tip of the Foley provides soft reinforcement of the tip that reduces curling of the catheter at the site of resistance.
- Alternatively, Chiou, Aggarwal, and Chen (2009) describe a simple and safe technique for placement of a catheter using a guidewire (**see FIGURES 66.25** and **66.26**) when a standard catheter does not pass into the bladder, especially in the case of urethral stricture. A Sensor hydrophilic guidewire can be inserted directly into the urethra. Rather than using force, which may lead to the formation of a false passage, place a guidewire into the bladder through the area of resistance, followed by passage of the catheter over the wire while the wire is in the bladder. A specialty catheter with a council tip is commercially available for this purpose and has a hole at the tip for passage over the wire; however,

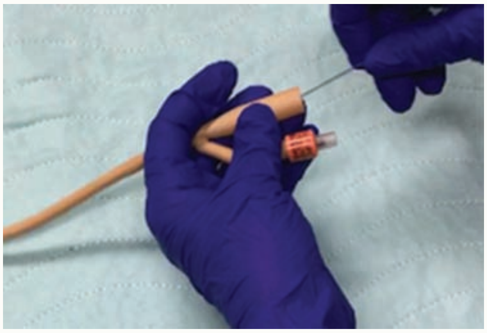
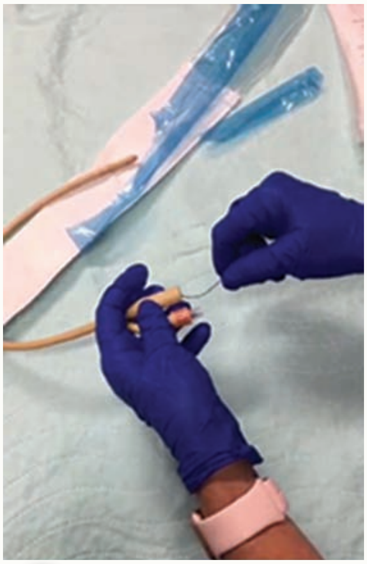


FIGURE 66.24 Inserting Sensor Guidewire (see **VIDEO 66.2** Insertion of glide wire into Foley prior to catheterization).



VIDEO 66.2 Guidewire in Foley demonstration.

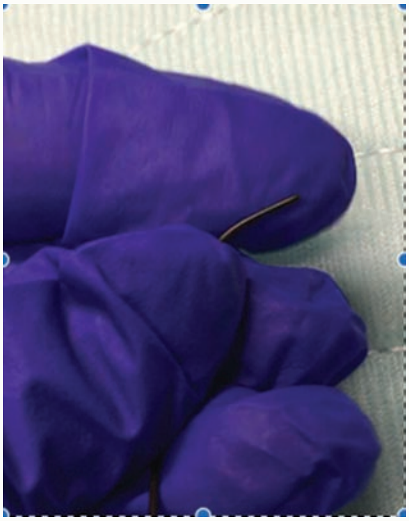


FIGURE 66.25 Sensor Guidewire hydrophilic tip. Note the flexible, soft tip that is inserted into the Foley or directly into the urethra.

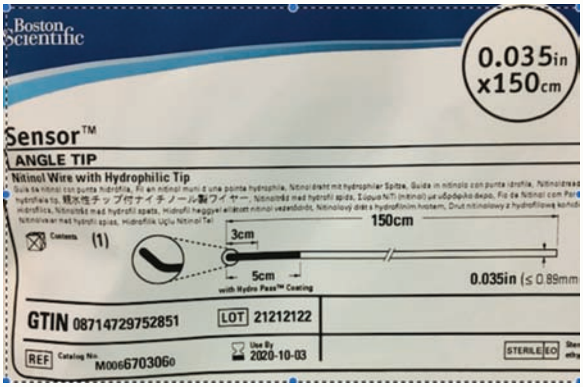


FIGURE 66.26 Sensor Guidewire hydrophilic angle tip.

Source: Boston Scientific, Marlborough , MA.

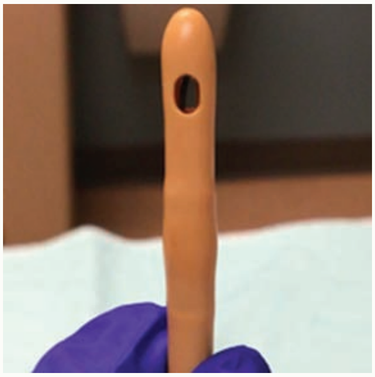


FIGURE 66.27 Tip of soft, flexible Sensor wire visible at end of Foley prior to insertion.

you should carefully snip the end of a standard straight-tip Foley and, prior to insertion, test the balloon to be sure there is no leak, and then insert the catheter over the wire. This guides the Foley into the bladder through a urethral stricture and avoids causing a false passage.

- Prior to inflating the balloon after a difficult catheter placement, especially if the flow of urine is not as robust as expected, flush the catheter with a 5-mL sterile NaCl flush; if it flushes easily, one can be assured the catheter is in the bladder and the balloon is not in the prostatic urethra.
- In some cases, especially in cases of infection, manual bladder irrigation can be very uncomfortable and mild sedation and/or administration of IV analgesic may be indicated in addition to local lidocaine gel.
- If a Rusch brand hematuria catheter is not available, or if it cannot be inserted due to prostate obstruction, a latex three-way catheter can be utilized for manual bladder irrigation, but it is less effective and more time-consuming.
- Regardless of the reason for placement of the urethral catheter, it is always necessary to obtain a urine sample, even if grossly bloody, and send this for culture.
- Utilizing POCUS prior to and after placement of catheters is useful for visualization of distended bladder, clots in the bladder, and demonstration of resolution of clots or retention as well as visualization of the balloon in the bladder.

MANAGEMENT OF SUPRAPUBIC CATHETERS

BACKGROUND

A suprapubic catheter is inserted into the bladder via a small incision in the abdominal wall to allow urinary drainage (**FIGURE 66.28**). A suprapubic catheter may be used for management of urinary incontinence, urinary retention, and neurogenic bladder. It may also be used temporarily after genitourinary trauma; for severe pelvic, perineal, or decubitus ulcers and infections; or following surgery (**FIGURE 66.29**).

The benefits of a suprapubic catheter versus a urethral catheter in patients requiring chronic indwelling urinary catheters include decreases in urethral discomfort, UTIs, urethral strictures, and urethral trauma. The suprapubic catheter is the indwelling catheter of choice for those patients who remain sexually active.

Suprapubic catheter sizes may vary, but most common sizes used in adult patients are either an 18- or 20-French two-way Foley catheter. Although there is no standard of care as to how often a suprapubic catheter should be changed, it is widely held that these catheters be changed every 4 to 6 weeks. More frequent intervals of suprapubic catheter changes may be necessary in the event of a UTI or an obstructed catheter that cannot be cleared with irrigation. It is important to note that if the catheter is displaced, dislodged, or nonfunctioning less than 4 to 6 weeks after initial placement by a urological surgeon, consultation with a surgeon is indicated before any manipulation of the catheter in the ED.

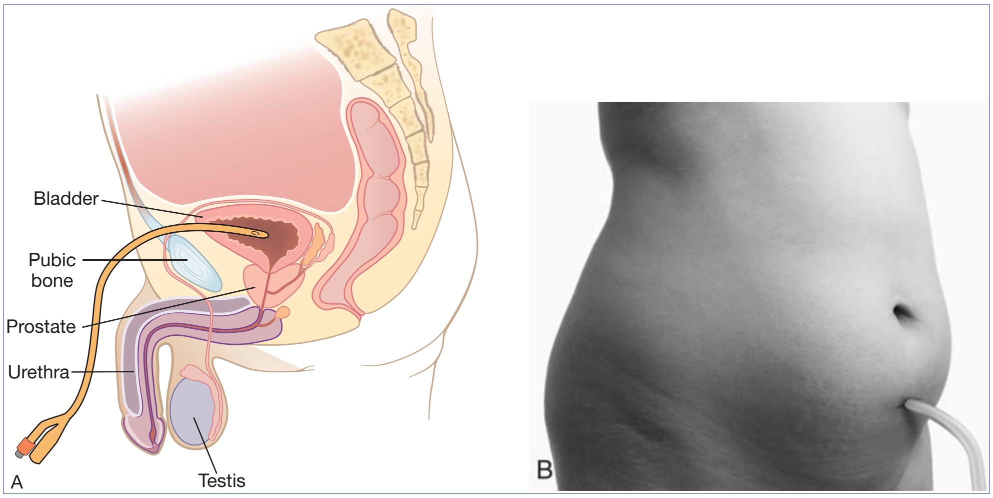
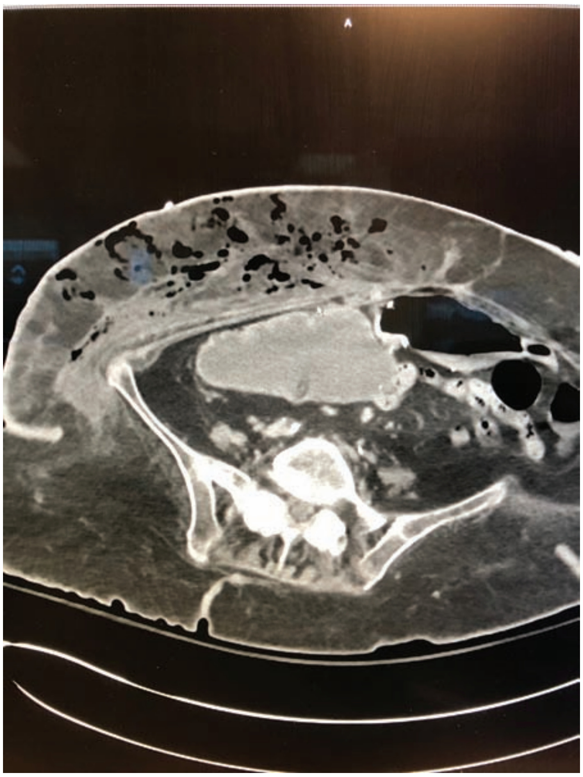


FIGURE 66.28 (A) Suprapubic catheter in place. (B) Suprapubic catheter in place in lower abdomen.

FIGURE 66.29 CT image of necrotizing fasciitis in a 60-year-old female with a history of neurogenic bladder requiring a long-term SP tube. Patient presented septic with significant induration, eschar, and crepitus surrounding the SP tube and CT notable for gas. Patient required extensive debridement emergently in the operating room.

SP, suprapubic.



PATIENT PRESENTATION

Patients may present with a variety of complaints regarding their suprapubic catheter:

- Symptomatic UTI (i.e., fever, hematuria, suprapubic pain, new onset of leakage at the stoma site)
- Bleeding from suprapubic stoma site
- Nondraining suprapubic catheter with suprapubic distention and bladder spasms with possible leakage around the catheter

TREATMENT

Urinary Tract Infection

Patients with chronic suprapubic catheters are likely to have chronic colonization of bacteria in the urine. The bacteria may consist of Gram-negative organisms, Gram-positive organisms, or yeast. It is recommended that patients with chronic urinary catheters not be treated with antibiotics for asymptomatic bacteriuria. However, a patient who presents with fever, chills, gross hematuria, suprapubic discomfort, or new onset of leakage from the stoma site may have an acute UTI. Leukocytosis may be present. Urinalysis (UA) often reveals white blood cells (WBCs), red blood cells (RBCs), bacteria, positive nitrate, and positive leukocyte esterase.

Bleeding From Suprapubic Stoma Site

Minor bright-red bleeding at the suprapubic catheter site is normal for 24 to 48 hours after the initial placement of the catheter. If this is noted, do not place traction on the catheter. With well-established suprapubic catheters, the most common cause of new onset of bleeding from the stoma site is excessive growth of granulation tissue. To treat granulation tissue and bleeding at the stoma, use silver nitrate sticks to cauterize the stoma edges and the granulation tissue, being careful to avoid contact with the catheter.

Obstructed Suprapubic Catheter

Patients may present with a urinary catheter obstructed by debris, blood clots, or calcification within the catheter. Assess the patency of the drainage tubing initially to rule out kinks causing obstruction. Irrigate the catheter with sterile water until drainage is reestablished. If obstruction persists, remove the catheter and replace with the same-size catheter.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- For patients with latex allergy, use latex-free or silicone catheters when replacing urinary catheters.

SPECIAL CONSIDERATIONS

If a suprapubic catheter must be changed, always question the patient regarding the date of the last catheter change. If the current catheter has been in place for more than 2 months, use caution when removing the catheter as it may be calcified. A flat plate x-ray of the abdomen may be done to assess for calcification of the catheter prior to removal.

In addition, in rare cases the balloon valve mechanism may fail in some catheters and attempts to deflate the balloon may result in no aspiration of fluid. It is important to fully deflate the balloon prior to attempting to remove the catheter; if uncertain, a bedside ultrasound can be utilized to visualize the balloon. If the balloon does not deflate with aspiration, the next step is to cut the balloon port (port that is used to fill and drain the balloon). It must be cut proximal to the plastic ring that is at the distal end; once cut, fluid should be noted to drain from the cut end of the port. Once fluid is noted, attempt to remove the catheter, or visualize it with bedside ultrasound. If resistance is still noted, consultation with urological services is indicated for further instrumentation and attempts to deflate the balloon.

PROCEDURE PREPARATION

Urinary Tract Infection

- Clean gloves
- Sterile gloves
- Skin cleanser
- Foley catheter (use the same size catheter that is currently in place)
- Sterile water-soluble lubricant
- 12-mL Luer-Lok syringe
- Sterile water
- Sterile urine specimen container

Bleeding From Suprapubic Site

- Clean gloves
- Silver nitrate sticks or electrocautery

Obstructed Suprapubic Catheter

- Clean gloves
- Sterile gloves
- 500- or 1,000-mL bottle of sterile water
- Irrigation tray with Toomey syringe
- Catheter supplies listed previously as needed

PROCEDURE

Urinary Tract Infection

- Assess the suprapubic catheter for size and patency.
- Use a Foley catheter of the same size as the catheter presently in place (to prevent difficulty in replacing the catheter in the suprapubic tract); this should be readily available for immediate replacement.
- Remove the suprapubic catheter by deflating the balloon, and discard in a biohazard container. A corkscrew technique may be necessary to remove the suprapubic catheter.
- Using aseptic technique, clean the suprapubic site with skin cleanser in a circular motion, moving from the stoma outward.
- Lubricate the catheter with sterile, water-soluble lubricant.
- Place the catheter in the stoma and insert a little farther than the catheter that was just removed.
- Wait for urine return. Obtain a sterile urine specimen for culture and sensitivity.
- Fill the 5-mL catheter balloon with 10 mL sterile water (to accommodate the fluid contained in the lumen of the catheter).
- Attach the suprapubic catheter to a closed urinary drainage system.
- Antibiotic choice depends on regional antibiograms and local resistance patterns; however, fluoroquinolones, second- or third-generation cephalosporins, or broad-spectrum carbapenems may be indicated. In case of systemic symptoms, aggressive antibiotic and sepsis prevention measures should begin immediately.
  - Ciprofloxacin 500 mg orally twice a day for 7 to 10 days
  - Levofloxacin 500 mg orally once a day for 7 to 10 days
- Patient should be admitted for urosepsis.

Bleeding From Stoma Site

- Cleanse the stoma site with normal saline.
- Using silver nitrate sticks or electrocautery, cauterize the stoma granulation tissue until bleeding ceases. The tissue will appear blackened in color.
- Apply triple antibiotic ointment to the site and apply a light sterile gauze dressing.
- Dressing should be removed after 24 hours.

Obstructed Suprapubic Catheter

- Aseptic technique should be used throughout the procedure.
- Ensure that there are no kinks in the tubing.
- Disconnect the Foley catheter from the urinary drainage-bag tubing.
- Using an irrigation set with a 60-mL catheter-tip syringe, instill 60 mL of sterile water to irrigate the catheter.
- Reassess for catheter patency. If patent, clean the distal tip of the urinary drainage-bag tubing with alcohol and reconnect to gravity drainage.
- If the catheter remains obstructed, replace the suprapubic catheter using the aforementioned steps.

POSTPROCEDURE CONSIDERATIONS

- Observe for hematuria following a suprapubic catheter change, irrigation, or manipulation.
- Secure the catheter with tape or a catheter-securing device so that there is no tension placed on the catheter.

EDUCATIONAL POINTS

- Instruct the patient on keeping the catheter drainage tube from becoming kinked, and on positioning the drainage bag below the level of the bladder to promote adequate drainage.
- Explain that minimal bleeding from the catheter is normal and may be intermittent in nature.
- The drainage bag should be emptied when one-half to two-thirds full.
- No urine output in the drainage bag and an urge to void may indicate obstruction of the catheter, and the patient should return for irrigation if needed.
- Notify the clinician if a fever develops.
- Instruct the patient to follow up with a urologist in a specified amount of time.

COMPLICATIONS

- Peritoneal placement of suprapubic catheter
- Development of urinary calculi
- Stomal stenosis
- Gross hematuria
- Increased risk of development of squamous cell carcinoma of the bladder

PEARLS

- Odor and discoloration may occur within the urinary drainage bag. The drainage bag may be cleaned with a solution of one-part vinegar and three-parts water.
- Patients with recurrent gross, painless hematuria should be encouraged to follow up with a urologist for a cystoscopic examination to rule out bladder calculi or bladder tumors.
- Always use gentle, constant pressure; never force the catheter into the stoma.
- If resistance persists, use a smaller sized catheter or call the urologist.

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CHAPTER

67

Procedures for Performing Paracentesis

Norah Wright and Richard Harrigan

BACKGROUND

Ascites is a condition in which excess fluid accumulates within the abdominal cavity (**FIGURE 67.1**). This is usually secondary to advanced liver disease, heart or kidney failure, cancer, an infection, or some combination of these entities. In the developed world, the most common cause is portal hypertension (PH) secondary to hepatic cirrhosis. Regardless of the cause, sequestration of fluid within the abdomen leads to intravascular fluid depletion, which stimulates aldosterone and renin production. This leads to increased fluid retention by the kidneys in order to compensate for the intravascular depletion. PH leads to splanchnic vasodilation (via nitric oxide) which eventually leads to sequestration of blood in the splanchnic-rich mesh of vascular arteries (**FIGURE 67.2**) and eventual decrease in GFR. Coupled with this, PH induces vasoconstriction to the arteries to the kidneys through an unknown mechanism and renal insufficiency may ensue; this is known as the hepatorenal syndrome.

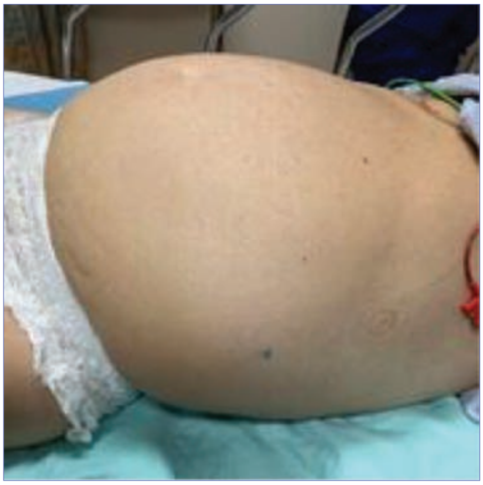

FIGURE 67.1 Typical patient with ascites; notice the protuberant abdomen, which usually has many liters of fluid within the peritoneal cavity, secondary to long-standing cirrhosis/PH. Accumulations up to 35 L have been reported.

PH, portal hypertension.

Paracentesis

- Paracentesis is a procedure done to remove ascitic fluid; either a needle or catheter is used for diagnostic and/or therapeutic purposes. Testing of ascitic fluid may help determine the etiology of the fluid accumulation as well as to evaluate for infection or the presence of cancer.
- When done for therapeutic purposes, the procedure may deplete serum albumin levels, so albumin is generally administered intravenously in proportion to the amount of ascites removed.
  - The AASLD (American Association for the Study of Liver Diseases) Guidelines (Runyon, 2012) recommend replacement with 6 to 8 g/L of 25% albumin after volumes over 4 to 5 L are removed.
- The serum-ascites albumin gradient (SAAG) is used to differentiate between transudative and exudative ascites.
  - ***The SAAG directly correlates with portal pressure***, and is calculated by subtracting the albumin concentration of the ascitic fluid from the serum albumin concentration obtained on the same day by a blood sample.
  - SAAG = serum albumin concentration − ascitic fluid albumin concentration
    - Prabakaran and Gowri (2016) looked at the SAAG score in 100 patients and found a strong correlation with the presence of esophageal varices and, in fact, the degree of varices. They concluded that the SAAG should be viewed as a preliminary and indirect method of estimating not only portal hypertension (PHT), but also its complications, such as esophageal varices (**TABLE 67.1**).

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

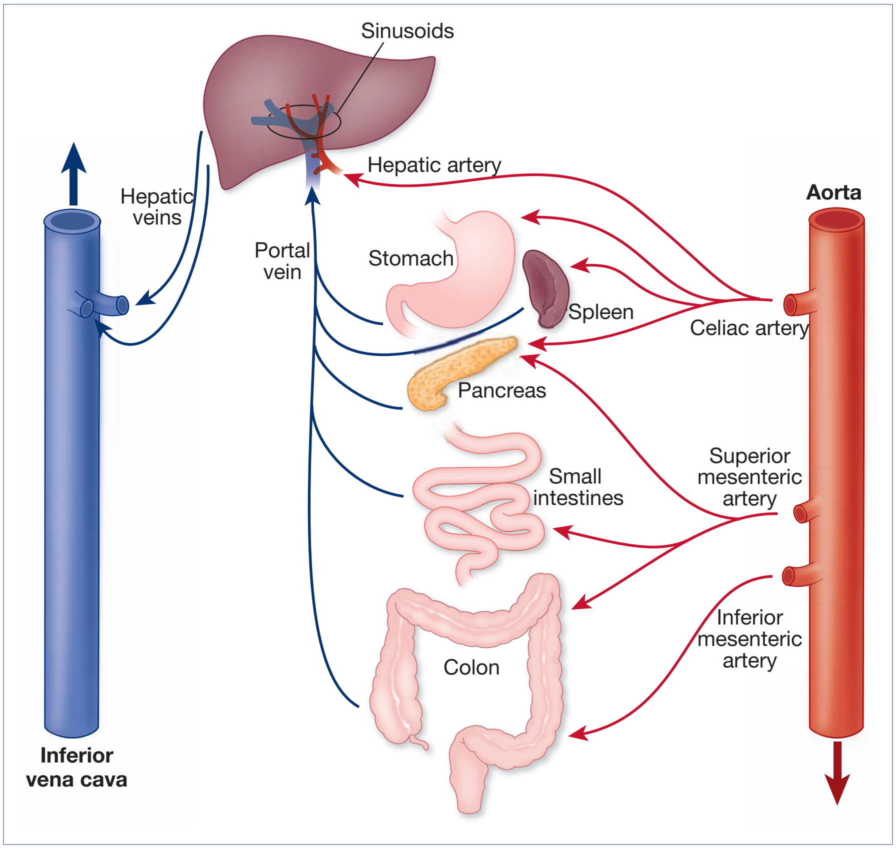
Sinusoids
Hepatic artery
Aorta
Hepatic veins
Portal vein
Stomach
Spleen
Celiac artery
Pancreas
Superior mesenteric artery
Small intestines
Inferior mesenteric artery
Colon
Inferior vena cava

FIGURE 67.2 Normal splanchnic circulation and the viscera it serves. The aorta supplies oxygenated blood to the viscera via the hepatic, celiac, and superior/inferior mesenteric arteries. Each of the visceral organs is drained via veins that feed into the portal vein, which in turn delivers blood to the liver. This large network of vasculature is known as the *splanchnic bed*.

- Other characteristics used to differentiate between transudative and exudative ascites are described in **TABLE 67.2**.
- Common causes of transudative ascites:
  - Hepatic cirrhosis
  - Congestive heart failure (CHF)
  - Nephrotic syndrome
  - Portal vein thrombosis
  - Malignancy
- Common causes of exudative ascites:
  - Peritoneal carcinomatosis
  - Infection (including tuberculosis [TB])
  - Inflammation of the
    - Pancreas (pancreatitis)
    - Biliary system
  - Peritonitis
  - Ischemic bowel

TABLE 67.1 SAAG With Mean Value of 1.48 + 0.44 g/dL as an Indicator of Presence of Esophageal Varices

Sensitivity	90%
Specificity	82%
Accuracy	89%

SAAG, serum-ascites albumin gradient.

TABLE 67.2 Characteristics of Transudative Versus Exudative Ascitic Fluid

	Transudate	Exudate
SAAG	>1.1 g/dL	<1.1 g/dL
Viscosity (specific gravity)	<1.016	>1.016
LDH	<400 U/L	>400 U/L
Protein	<3.0 g	>3.0 g
WBC	Few	Many

LDH, lactate dehydrogenase; SAAG, serum-ascites albumin gradient; WBC, white blood cells.

Spontaneous Bacterial Peritonitis

- Spontaneous bacterial peritonitis (SBP) is a condition in which the ascitic fluid becomes ***infected*** secondary to a process known as *translocation*.
  - The key pathogenic mechanism initiating this clinical entity is the movement (translocation) of enteric bacteria crossing the intestinal barrier and infecting the mesenteric lymph nodes, thereby entering the ascitic fluid and sometimes the systemic circulation. The high rate of bacterial translocation in cirrhosis is thought to be secondary to the following:
    - Injury to the intestinal mucosal barrier ensues because of cirrhosis/PH:
      - Homeostatic balance of intraluminal bacterial flora is jeopardized.
      - Integrity of the intestinal epithelial barrier is violated.
      - Local immune system is depressed.
    - Next to urinary tract infections (UTIs), SBP is the most common infection in patients with advanced liver cirrhosis.
      - Incidence
        - ❑ Outpatients—3.5%
        - ❑ Inpatients—12%
- Common pathogens include *Escherichia coli*, *Klebsiella pneumoniae*, Enterococcal species, and *Streptococcus pneumoniae*.
- Patients receiving peritoneal dialysis (5% in economically developed regions like the United States and Western Europe to as much as 75% in Mexico) for renal failure are at increased risk of SBP.
  - Peritoneal dialysis-related SBP is complicated by:
    - Relapse—14%
    - Catheter removal—22%
    - Permanent haemodialysis (HD) transfer—18%
    - Mortality—4%
- An ascitic fluid neutrophil count over 250 cells/µL is presumptive of SBP, which can only be confirmed with ascitic fluid culture, with Gram stain being notoriously insensitive.
  - Hardick et al. (2012) have shown that using a newer broad-range polymerase chain reaction (PCR; detects small amount of bacterial DNA) increased the sensitivity and specificity to 100%/92%, respectively.

Any patient with suspected SBP should be treated empirically with antibiotics due to the morbidity and mortality associated with this condition. Orman, Hayashi, Bataller, and Barritt (2013) have shown that early paracentesis (<12 hours from time of admission) improves the short-term survival of patients hospitalized with SBP.

PATIENT PRESENTATION

- Patients with ascites will generally complain of abdominal distension, weight gain, anorexia, and dyspnea (thought to be secondary to the mechanical forces affecting the diaphragm and, in some cases, concomitant pleural effusions).
- Other symptoms may include nausea and vomiting, fatigue, peripheral edema, and increased abdominal girth.

- On physical examination, ascites is demonstrated by:
  - Flank bulging
    - Visible bulging of the flanks in the reclining position.
  - Shifting dullness
    - Difference in percussion noted in the flanks when moving the patient from supine to lateral decubitus positioning.
  - Fluid wave
    - Tapping one side of the abdomen generates a wave effect that may be palpable on the other side of the abdomen.
    - Lower sensitivity than these other physical exam findings as it requires a significant amount of fluid in the peritoneal cavity.
- The diagnostic accuracy of physical exam assessment:
  - Sensitivity: 50% to 80%
  - Specificity: 82% to 92%
  - Predictive value: Greater than 70%
- As there is wide discrepancy in exam findings despite astute and meticulous physical assessment skills, point of care ultrasound (POCUS) is now regarded as the gold standard in ascites diagnosis.

Depending on the etiology of ascites, there may be other physical examination findings associated with that condition. For example, in PH from hepatic cirrhosis, patients may exhibit ecchymoses, gynecomastia, testicular atrophy, hemorrhoids, dependent edema, mental status changes, and caput medusa (distended superficial epigastric veins). Patients with ascites secondary to peritoneal carcinomatosis may also demonstrate chronic fatigue and weight loss. Patients with ascites from heart failure may complain of dyspnea on exertion, orthopnea, and display jugular vein distention (JVD) and a S3 gallop.

TREATMENT

- The diagnostic workup for new ascites may include bloodwork (typically complete blood count, basic metabolic panel, liver enzymes, and coagulation studies), abdominal ultrasound (US) and/or abdominal CT, and an echocardiogram.
- Treatment is then directed toward correcting the condition that is causing the ascites.
- Often a low-salt, fluid-restricted diet in combination with prescribed diuretics is used to attempt to remove this excess fluid when it is causing minimal symptomatology; however, if this is not effective and/or symptoms escalate, a paracentesis will need to be performed.
- If recurrent paracenteses are required, the hepatologist may consider a transjugular intrahepatic portosystemic shunt (TIPS; shunt placed from the variation in the inferior vena cava [IVC] through the liver to the portal vein bypassing the liver in an effort to decrease PH and its sequalae). Liver transplant, when appropriate, provides more definitive care.
  - Piecha et al. (2019) looked at 128 patients with refractory ascites.
    - Post-TIPS ascites control was achieved in 74% of the patients.
    - A further review showed that TIPS placement in patients with lower paracentesis frequency and creatinine levels was associated with superior ascites control and thus recommended that TIPS implantation should be considered in moderate decompensation and not as a last resort.
- A diagnostic paracentesis may be used in the workup of new-onset ascites, suspected SBP, or refractory symptomatic ascites.
  - A therapeutic paracentesis may be performed to relieve respiratory distress or abdominal compartment syndrome caused by large volume ascites.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Absolute

- An acute abdomen
- New-onset abdominal ascites after trauma with clinical suspicion for hemoperitoneum
  - Will require laparotomy or embolization

Relative

- Severe thrombocytopenia (platelet count $<20 \times 10^3$ μL)
  - Correct with platelet transfusion
- Coagulopathy (international normalized ratio [INR] >8.0) and/or thrombocytopenia
  - Correct with fresh frozen plasma (FFP) or prothrombin complex concentrate (PCC)
- Disseminated intravascular coagulation (DIC)
- Pregnancy
  - POCUS can identify uterus and area of largest fluid pocket.
- Bladder distension
  - Correct with void/bladder catheter
- Abdominal wall cellulitis
  - Avoid area
- Distended bowel
  - Decompress with placement of a nasogastric tube (NGT)
  - POCUS can find the largest fluid pocket and identify/avoid bowel loops.
- Intraabdominal adhesions
  - POCUS can find the largest fluid pocket.

SPECIAL CONSIDERATIONS

- Depending on the clinical situation, the ascitic fluid may be sent for laboratory testing, including:
  - Cell count
  - Gram stain
  - Bacterial culture
  - Albumin (SAAG)
  - Total protein
  - Triglyceride
  - Bilirubin
  - Glucose
  - Amylase
  - Lactate dehydrogenase (LDH)
  - Cytology

PROCEDURE PREPARATION

This procedure is performed under typical sterile precautions, including sterile hat, mask, gown, and gloves.

- Diagnostic paracentesis
  - Antiseptic preparation
  - Local anesthetic (LA)
  - 20-mL syringe
  - 18-gauge or smaller needle
- Therapeutic paracentesis
  - Paracentesis kit (**FIGURE 67.3**)
- Hemodynamic monitoring when large volumes removed

In order to minimize the risk of persistent leakage from the puncture site, a "Z"-track needle-insertion technique may be used. To do this, the skin is held taut while the needle is inserted into the muscle, which causes a "zig-zag" tracking of the needle through the skin, subcutaneous tissue, and muscle and prevents leakage postprocedure (**FIGURE 67.4**). Alternatively, a pressure dressing and/or single skin suture (persistent leak) may be placed after the procedure.

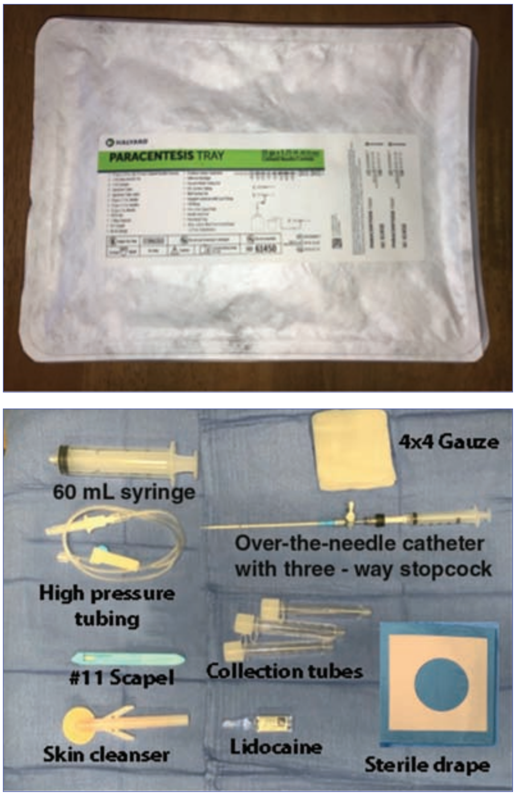

FIGURE 67.3 Paracentesis procedure kit.

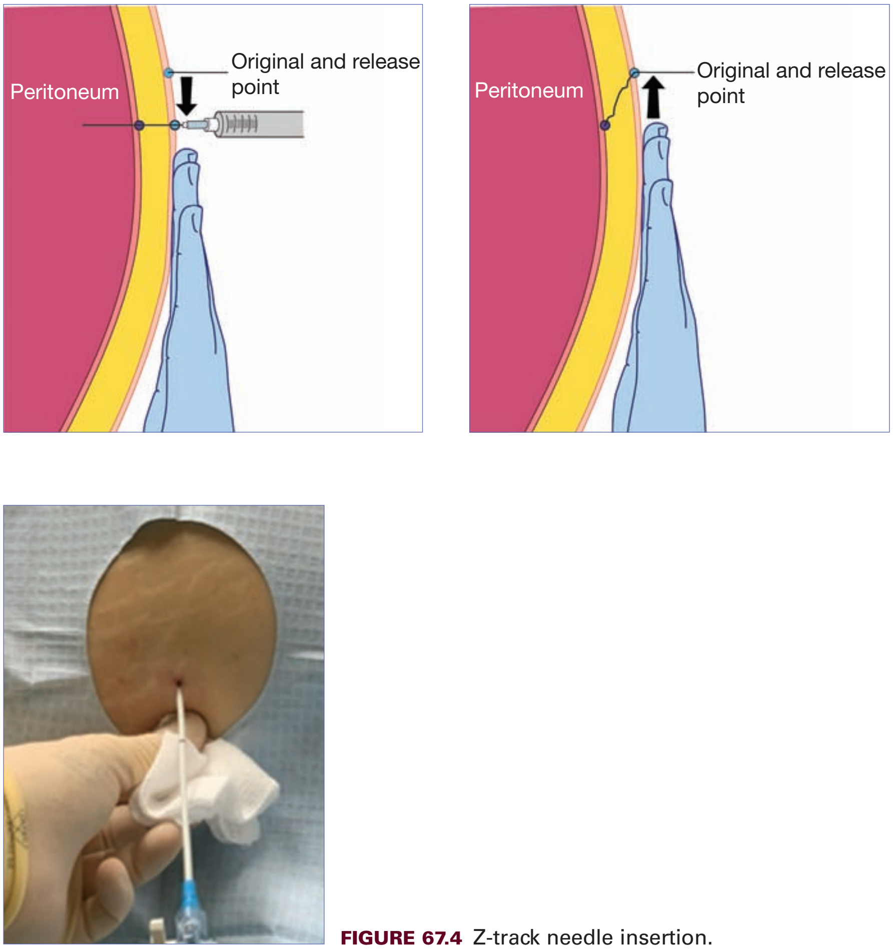

FIGURE 67.4 Z-track needle insertion.

PROCEDURE

- After the presence of ascites is confirmed, informed consent is obtained before beginning the procedure of abdominal paracentesis.
- The patient should be instructed to urinate prior to the procedure in order to empty their bladder.
- Local anesthesia using an injection of lidocaine with epinephrine is useful to minimize pain and bleeding associated with the procedure.
- Procedural sedation is rarely required, but medications to minimize pain and anxiety may be useful adjuncts when needed.

Positioning

- Patients with significant ascites are often positioned supine; however, a modified lateral decubitus positioning (i.e., hip and buttocks elevated on side opposite to needle insertion) can help to increase the success of the procedure in patients with smaller volume ascites.
- The bed can be elevated to 45 to 60 degrees (reverse Trendelenburg) in order to allow fluid to accumulate in the lower abdomen.
- As abdominal ascites are gravity dependent, the point of entry should be near the stretcher when patients are in a modified lateral decubitus position.
- To avoid areas of prominent abdominal wall veins (caput medusa), infected skin, or scar tissue, careful attention should be used when choosing an entry site.

Location

- Historically, the recommended insertion sites are either 2 cm below the umbilicus midline through the linea alba, or 5 cm superior and medial to the anterior superior iliac spine on either side of the abdomen (**FIGURE 67.5**).
  - Today, with the ubiquity of POCUS, areas with the largest fluid pocket can be selected while, at the same time, abdominal wall vascularity (inferior epigastric vessels) can be identified for avoidance.
    - Bleeding complications have been observed in less than 1% of patients using US guidance.
- Ultrasonography can be used to verify the presence of a fluid pocket under the selected entry site, and can also be used to ensure that the patient's bladder has been emptied (**FIGURE 67.6**).

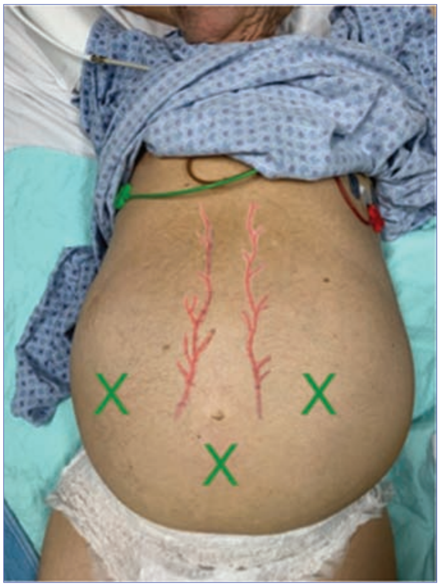

FIGURE 67.5 Needle entry sites depicted in an effort to avoid penetration into inferior epigastric vessels (artery and vein).

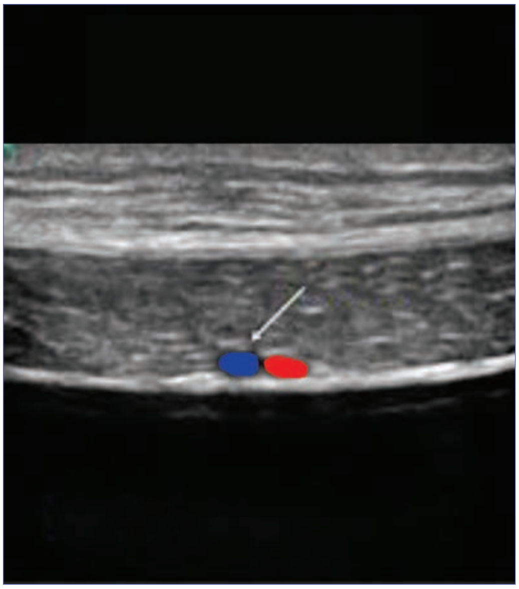

FIGURE 67.6 Doppler ultrasound showing the abdominal wall, epigastric vessels, ascites, and loops of bowel.

Sterile Precautions

- Precautions should be used in order to maintain a sterile field. Sterile gown, face mask, and sterile gloves should be used.
- The first step is to prepare the skin with an antiseptic solution.
- Next, a sterile fenestrated drape should be placed in order to maintain a sterile field.

Anesthesia

- A small skin wheal should be made at the skin entry site by injecting lidocaine with epinephrine with a 25- or 27-gauge needle, and then injecting a small amount along the catheter insertion tract down to the peritoneum (**FIGURE 67.7**).
- Intermittent aspiration while anesthetizing the insertion tract should be used in order to identify return of ascitic fluid once the peritoneum is entered.
- Special attention should be made to the depth of insertion when ascitic fluid returns within the lidocaine syringe as this will be useful in the following steps.

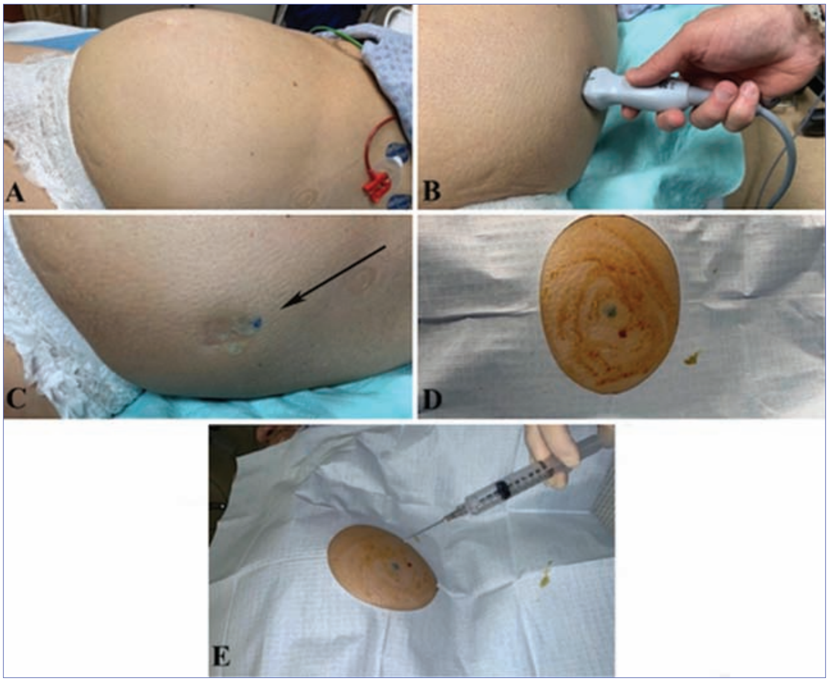

FIGURE 67.7 Procedure preparation. (A) Lay the patient supine. (B) Use ultrasound to identify the largest pocket of ascites as well as the safest entry site; this makes use of static ultrasound (*dynamic ultrasound* is when one uses the ultrasound probe throughout the entire period of needle placement, as in placing a central line). (C) Mark the entry site (see arrow). (D) Prepare skin with skin cleanser and sterile drape. (E) Inject local anesthetic at the entry site.

Diagnostic Paracentesis

- For a diagnostic tap, an 18-gauge needle (or smaller) attached to a 20-mL syringe is inserted perpendicular to the skin entry point with continuous syringe aspiration until ascitic fluid is removed (**FIGURE 67.8**).
    - As an alternative, one can use a sterile phlebotomy needle/vacutainer setup and introduce appropriate specimen tubes into the vacutainer to obtain ascitic fluid.
- The needle should not need to be inserted any deeper than 1 cm beyond the depth at which ascitic fluid was noted within the lidocaine syringe or seen on US.
    - To gauge the depth of the abdominal wall/peritoneum distance, one can/should use the calibrated scale typically shown on the right-hand side of the US monitor (**FIGURE 67.9**).
- Once the desired amount of ascitic fluid has been obtained, the needle is removed and a bandage or dressing is placed over the entry site.

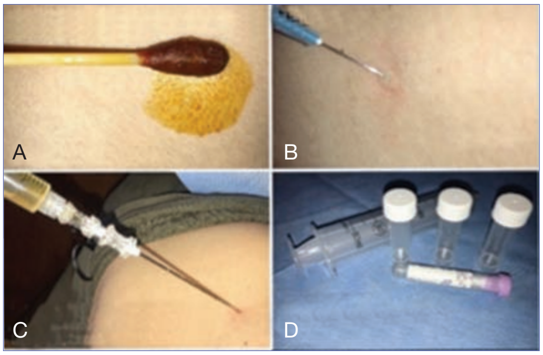

FIGURE 67.8 Steps to performing a diagnostic paracentesis. Dynamic application of point-of-care ultrasound should be utilized if the ascites volume is small (refer to **FIGURE 67.9**). (A) Prepare skin with antiseptic. (B) Inject skin wheal with 1 cc lidocaine with epinephrine. (C) Insert 18-gauge needle perpendicular to the skin and withdraw until ascitic fluid is aspirated. (D) Label and send for any desired studies. Place dressing over entry site.

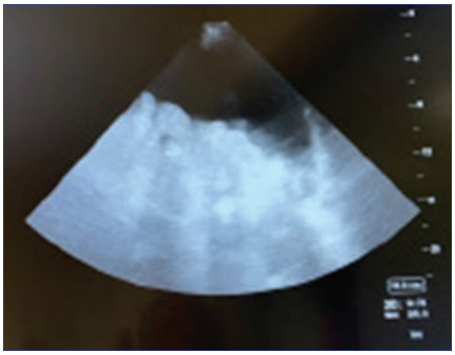

FIGURE 67.9 Use marked distance scale to calculate the depth needed for needle penetration into the peritoneal cavity. Note one should limit needle advancement 1 cm past this number.

Therapeutic Paracentesis

- For a therapeutic tap, an 11-blade scalpel is used to make a small skin nick in order to allow easier passage of the catheter.
- An 8 French catheter over an 18-gauge, 7.5-inch-long needle is slowly inserted perpendicular to the skin entry point with continuous syringe aspiration until entry into the peritoneal cavity is achieved and ascitic fluid begins to fill the syringe.
- A loss of resistance may be noted as the deep fascia/peritoneum is disrupted. The needle is then inserted another 2 to 5 mm into the peritoneal cavity (no more than 1 cm beyond the depth at which ascitic fluid was noted within the lidocaine syringe and/or US scaled distance).
- While firmly anchoring the needle in place, the catheter is then advanced over the needle completely into the peritoneal cavity. The needle can be removed and a 60-mL syringe can be attached to the catheter in order to aspirate the ascitic fluid (**FIGURE 67.10, VIDEO 67.1**).

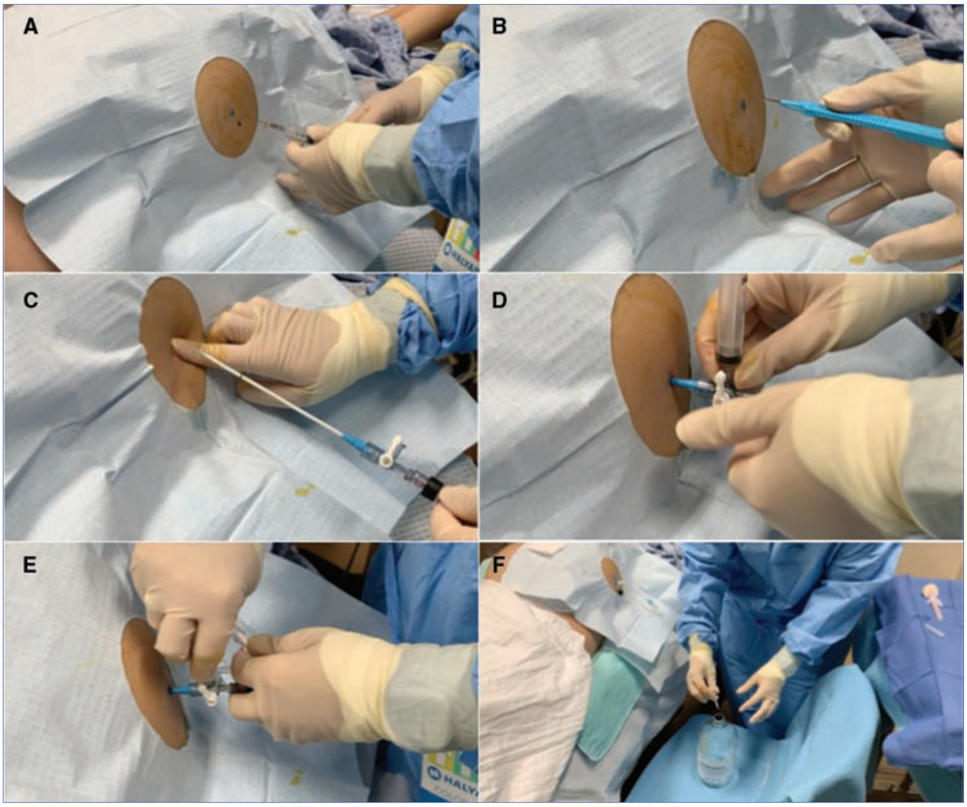

FIGURE 67.10 Steps to performing a therapeutic paracentesis. (A) After POCUS static guidance and skin cleansing, inject LA. (B) Use an 11-blade scalpel to create a small skin nick in order to prevent the catheter from kinking upon skin entry. (C) Direct the catheter perpendicular to the skin utilizing distal control and a twisting motion, all the while applying slight negative pressure on the plunger. (D) Utilize the three-way stopcock and remove fluid for testing from the superior port and place in tubes for laboratory analysis. (E) Remove syringe and replace with high-pressure tubing. (F) Attach high-pressure tubing to vacutainer bottles.

LA, local anesthetic; POCUS, point-of-care ultrasound.

VIDEO 67.1 Therapeutic paracentesis.

- Next, the fluid collection tubing may be connected by way of a three-way stopcock to the catheter, and large "vacutainer" suction bottles under vacuum seal can be used to remove large-volume ascites in a timelier manner (**FIGURE 67.11**).
- If occlusion of the catheter occurs and flow of ascitic fluid stops, rotation of the catheter may restore flow.
  - If flow is not restored, the end of the catheter may be against bowel; attempt to roll and/or sit patient up as well as retract catheter slightly (once retracted, do not readvance).
- Once the desired amount of fluid is obtained, the catheter is removed and firm pressure is applied to the entry site in order to stop any bleeding that is present.
- A bandage is placed over the skin puncture site and the procedure is completed.

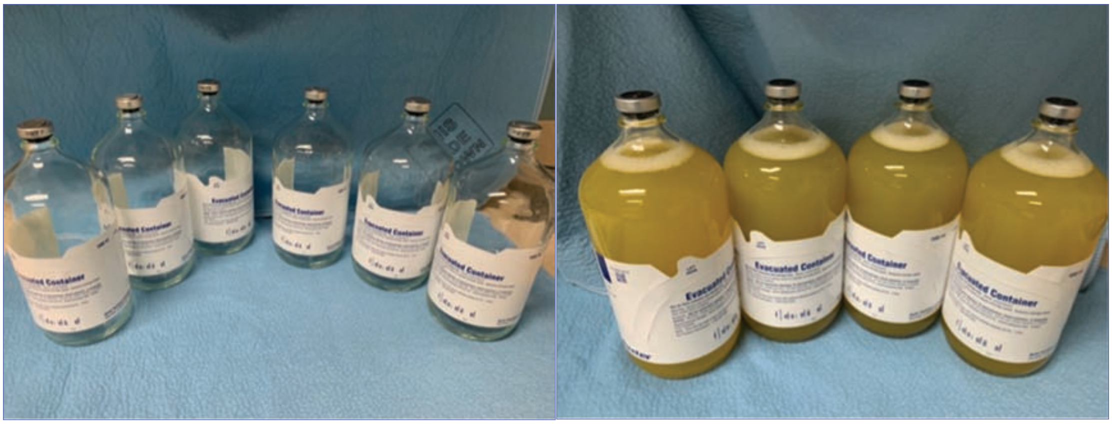

FIGURE 67.11 Typical return of a therapeutic paracentesis. Note that it is important to have more bottles than anticipated.

ULTRASOUND GUIDANCE

- Ultrasound (US)-guided paracentesis is becoming an increasingly utilized tool in order to confirm the presence and quantity of ascites, determine the safest needle trajectory, avoid the epigastric blood vessels, and to check the position of the needle prior to dilation.
- Fluid appears anechoic inferior to the echogenic abdominal wall musculature.
- Bowel will be seen as a moving, echogenic structure floating within the fluid.
- The deepest pocket of fluid identified on US demonstrates the safest location for paracentesis needle insertion (**FIGURE 67.12**).
- The *ascites index* is an US technique used to estimate the volume of abdominal ascites. This is done as a summation of ascites volumes calculated from each of the four abdominal quadrants.
- If a large pocket of fluid is identified, one can use a mark on the skin as a target and in this way use the POCUS in a ***static*** way.
- In cases in which there is only a small amount of fluid, usually in regard to a diagnostic procedure, benefit will be had from conducting the entire paracentesis procedure under US guidance, that is, in a dynamic way; the tip of the needle will appear as a hyperechoic structure entering the abdominal wall into the fluid, avoiding bowel and/or viscera (**FIGURE 67.13**).
- In addition, a newer, noninvasive method of differentiating exudative from transudative ascites is done by using a histogram of grayscale pixels obtained by B-mode US; in this technique, the ascites-to-rectus abdominis muscle echogenicity ratio (ARAER) is measured.
  - A value greater than 0.002 indicates exudative ascites, and a value less than 0.002 indicates transudative ascites; this measurement does not negate the need for laboratory analysis.

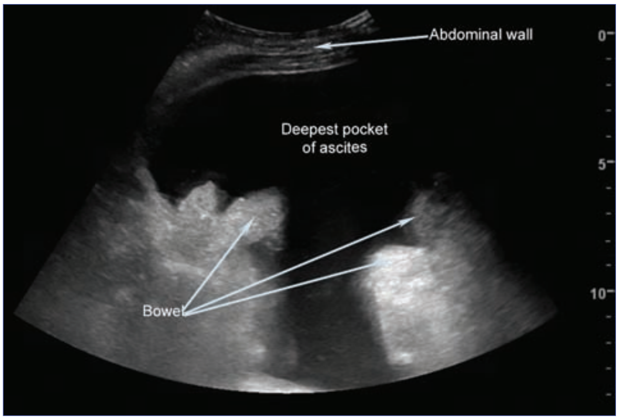

FIGURE 67.12 Always insert needle into the deepest pocket of fluid.

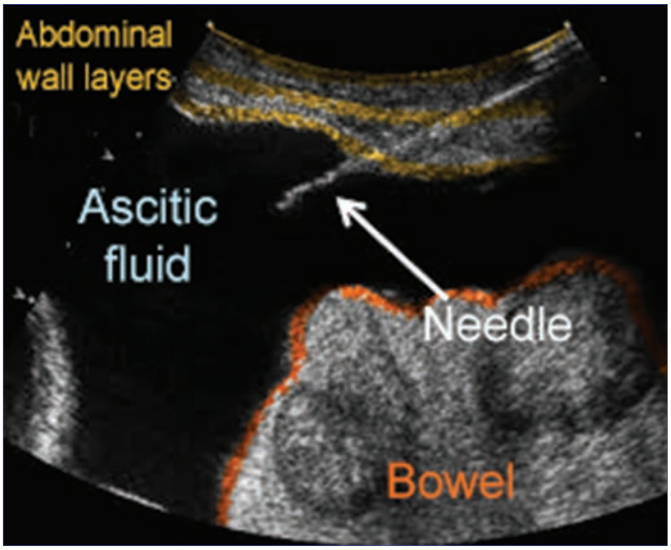

FIGURE 67.13 Dynamic needle placement, usually used for a diagnostic (not therapeutic) tap when fluid is minimal. Note that the needle in plain view is seen avoiding the bowel wall while moving toward the deepest pocket.

POSTPROCEDURE CONSIDERATIONS

- Depending on the amount of fluid removed and the hemodynamics of the patient, colloids (albumin) may need to be administered after the procedure to restore intravascular volume.
  - Supplementing 5 g of albumin per each liter over 5 L of ascitic fluid removed decreases complications of paracentesis, such as electrolyte imbalances, hypotension, and increases in serum creatinine levels secondary to large shifts of intravascular volume.
    - The AASLD indicates that postparacentesis albumin infusion may not be necessary for a single paracentesis of less than 4 Ls; however, for large-volume paracenteses, an albumin infusion of 6 to 8 g per liter of fluid removed appears to improve survival and is recommended.
    - A simpler method is to administer 25% (12.5 g) of albumin for every 2 L of ascites removed (**FIGURE 67.14**).
- Additional platelet transfusion or FFP administration may be required in the case of severe bleeding postprocedure.
- Provided there are no complications or concerns for infection, the patient can typically be discharged home after a few hours of stable postprocedure observation.

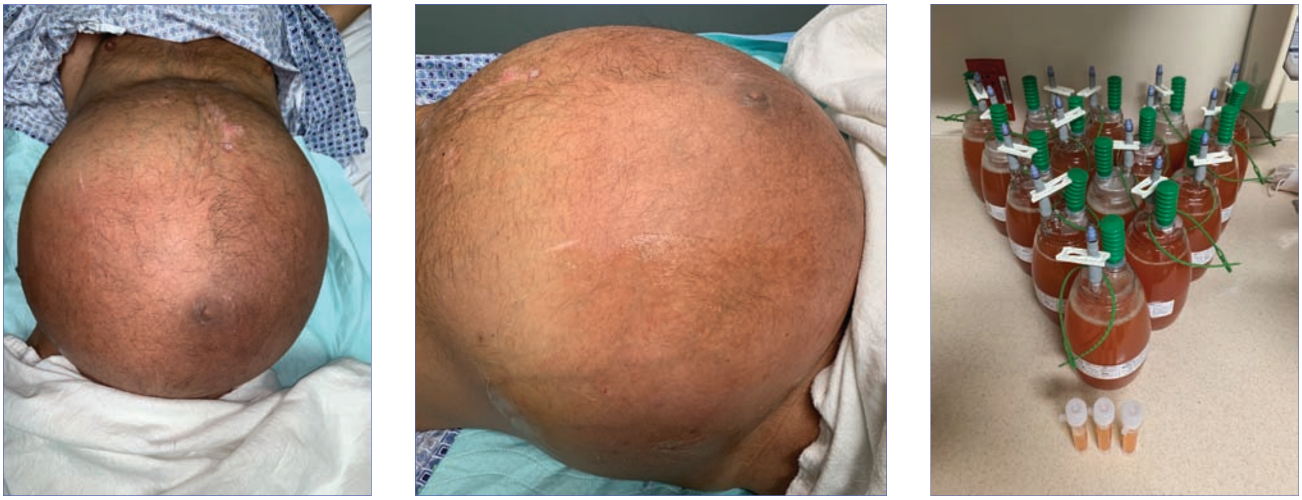

FIGURE 67.14 Large volume of ascites removed in patient with respiratory distress. Note the use of Luer Lock needles with plastic containers. Because 15 L were removed from the peritoneal cavity, 93.75 g of albumin was infused with no sequela of intra- or postprocedure hypotension (12.5 g of albumin given for each 2 L of ascites removed or 6.25 g per liter).

EDUCATIONAL POINTS

- Ascites is most commonly caused by PH secondary to hepatic cirrhosis.
- Paracentesis is a safe bedside procedure done to diagnose the cause of ascites, determine the presence of infection or cancer, and relieve the symptoms associated with abdominal distension; it is diagnostic as well as therapeutic.
- The SAAG is used to differentiate between transudative and exudative ascites. A SAAG greater than 1.1 indicates transudative ascites; transudative ascites is typically caused by hepatic cirrhosis, heart failure, or nephrotic syndrome; exudative ascites is typically caused by cancer or infection.
- SBP occurs when the ascitic fluid becomes infected due to translocation of enteric bacteria; this entity is presumed with an ascites neutrophil count greater than 250 cells/μL and can be confirmed by ascites fluid culture, though the yield is low by such.
- Prior to performing a paracentesis, correction of thrombocytopenia and coagulopathy is rarely required in order to reduce the risk of bleeding associated with the procedure itself; POCUS can be used to minimize the other procedural complications (failure to collect fluid, hollow viscous perforation, and laceration of major blood vessels/viscera).

COMPLICATIONS

- Common complications include bleeding and introduction of infection. Other complications may include failure to collect peritoneal fluid, persistent leak from the puncture site, abdominal wall hematoma, spontaneous hemoperitoneum, hollow viscus perforation, laceration of a major blood vessel, or dilutional hyponatremia.
- Postparacentesis hypotension is a delayed complication after large-volume therapeutic paracentesis. This may occur more than 12 hours postprocedure and the risk can be minimized with preprocedure colloid (such as albumin) administration.

PEARLS

- Consider albumin infusion in cirrhotic patients with large-volume paracentesis in order to reduce the risk of circulatory dysfunction as well as in septic patients with SBP.
- Inserting the needle either in the midline or lateral lower quadrant (lateral to the rectus abdominis muscle and 2 to 4 cm superior and medial to the anterior superior iliac spine) helps to avoid puncture of the inferior epigastric arteries as well as avoid visible superficial veins and surgical scars; however, because of anatomic anomalies and/or challenging bodily habitus, POCUS trumps anatomic landmarks.
- Inserting the needle using a Z-tracking technique helps to reduce the risk of postprocedure ascites fluid leak.
- Careful attention not to mistake the bladder or cystic abdominal masses for ascites must be undertaken when performing this procedure under US guidance; ensuring the patient empties their bladder before beginning the procedure helps minimize this risk.

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CHAPTER 68

Procedures for Removal of Rectal and Vaginal Foreign Body

Samantha Huo, Maura Sammon, and Ryan Schultz

RECTAL FOREIGN BODIES

BACKGROUND

Rectal foreign bodies are an infrequent presentation in the ED. Those with a rectal foreign body (FB) often self-report and request object removal. Less common, embarrassment may prevent patients from providing an accurate history. The diagnosis and management of rectal FB can be complex. Although the majority of patients will provide an accurate history, some patients may delay presentation or not be fully forthcoming. Alternative presenting symptoms may include lower abdominal pain, rectal bleeding, and constipation. Cases have been reported in all age groups, genders, and ethnicities, though most frequently among men. In the vast majority of cases, rectal FBs usually are inserted as a result of erotic activity and sex toys are therefore the most common objects requiring removal. Some rectal FBs are initially swallowed and then transit through the gastrointestinal (GI) system. Examples of the latter include toothpicks, popcorn, bones, and sunflower seeds.

The most commonly implicated objects include:

- Sex toys
  - Vibrators
  - Dildoes
- Drug paraphernalia (packets)
  - Placed for concealment
- Toothbrushes
- Deodorant bottles
- Light bulbs
- Sharp objects (usually psychiatric patients)
  - Nails
  - Screwdrivers

It is important to evaluate signs of peritonitis when evaluating these patients. Signs of tachycardia, fever, and hypotension are particularly worrisome and warrant additional diagnostic tests and treatment. ***Prior to any digital rectal examination, a CT or x-ray of the abdomen/pelvis should be obtained to prevent provider injury secondary to sharp objects*** (**FIGURE 68.1**).

It is also important to consider the duration of symptoms, the possibility of body packing, and any concerns over possible sexual assault (**FIGURE 68.2**). Sexual abuse should particularly be considered in children who present with recurrent rectal FBs.

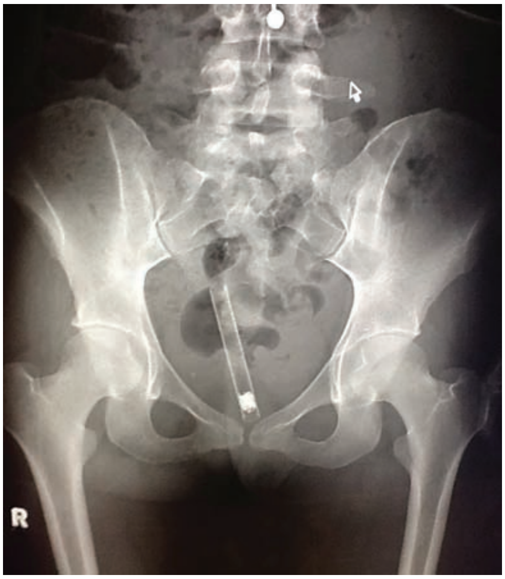

FIGURE 68.1 Crack pipe as rectal foreign body.

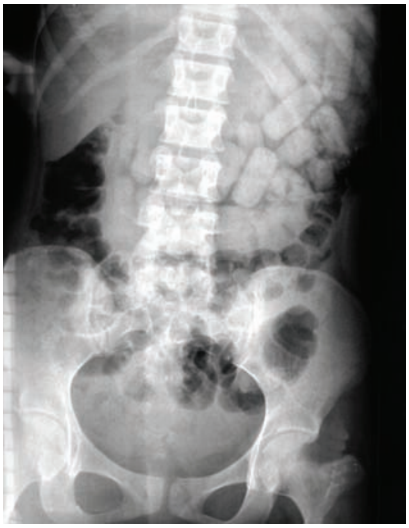

FIGURE 68.2 Body packing showing radiopaque tied condoms, each containing large quantities of cocaine, ingested in an effort to avoid law enforcement. This is a critical finding as supralethal amounts of cocaine exist in each condom. ICU monitoring, cathartic, and surgical standby are required (immediate laparotomy required if clinical symptomology displays any sign of condom rupture indicating a sympathomimetic crisis).

Repeated rectal FBs may also be a manifestation of underlying psychiatric illness. Reasons for operating room (OR) consult and surgery removal include:

- Possible injury to the anal sphincter
- Risk of perforation
- Failure of ED removal

Objects that are above the rectosigmoid junction (sacral tip area/narrowest part of the large intestine) are difficult to visualize and remove, and they are often unreachable outside of the OR. Note the average adult rectum/anus is 12 cm/4 cm, respectively, and becomes dilated at the rectum ampulla as it terminates. The entire anus is extraperitoneal, whereas the proximal two-thirds of the rectum is partially covered with a peritoneum deflection (**FIGURE 68.3**). Low-lying rectal FBs, however, are normally palpable on digital examination and are candidates for ED removal (**FIGURE 68.4**).

It is important to evaluate the patient for signs and symptoms of peritonitis, as FBs may cause damage to local structures (mucosa) and lead to bowel perforation, although this is rare. Tachycardia, fever, and hypotension are particularly worrisome and warrant additional diagnostic tests. It is also important to consider the type and shape of the FB, duration and recurrence of symptoms, intentional versus accidental insertion, and whether the object was inserted consensually. Sexual abuse should be considered in all children who present with a rectal FB, particularly if the behavior is recurrent. As indicated, psychiatric illness should be considered. The possibility of body packing raises concerns over rupture of the drug packet and exposure of the patient to its contents (e.g., heroin or cocaine toxicity).

Clinical examination of a suspected rectal FB includes an abdominal examination and imaging. A concerning initial examination should be followed by a CT scan of the abdomen and pelvis. CT scan is not routinely needed for straightforward presentations; an upright x-ray of the abdomen/pelvis may be obtained in most cases. A digital rectal examination should then be performed, ***only after ensuring the FB is not sharp***, though inability to palpate an FB on rectal examination does not rule out its presence as it may be located more proximally.

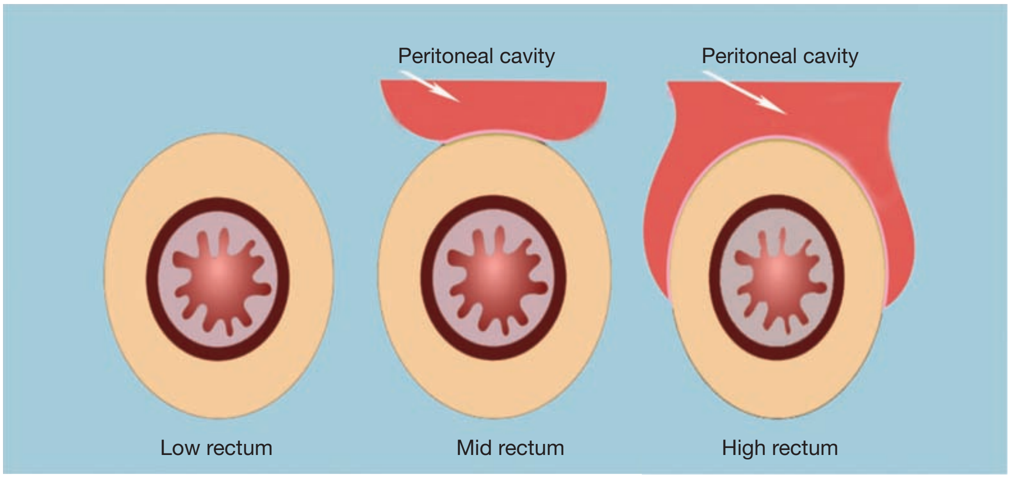

FIGURE 68.3 In the superior third of the rectum, the anterior surface and lateral sides are covered by peritoneum. The middle third only has an anterior peritoneal covering, and the lower third has no peritoneum associated with it.

Source: Courtesy of van Loenhout, R., Zijta, F., Lahaye, M., Beets-Tan, R., Smithuis, R. (2015). Rectal cancer—MR staging 2.0. *Radiology Assistant*. Retrieved from https://radiologyassistant.nl/abdomen/rectal-cancer-mr-staging-2-0

PATIENT PRESENTATION

- Rectal bleeding
- Mucus discharge
- Constipation
- Lower abdominal or pelvic pain
- Peritonitis
- Sympathomimetic crisis in regard to body packing
- Symptoms may be nonspecific in pediatric patients.

TREATMENT

If operative intervention is not necessary (perforation), then manual manipulation of the FB can be attempted in adults. The patient should first be placed in the lithotomy, knee-to-chest, or Sims position to provide for better object visualization (see text that follows). Adequate sedation and analgesia are critical prior to attempting object removal, as anal spasm and patient discomfort may hinder object visualization and exposure. A perirectal nerve block can be performed using 1% lidocaine with epinephrine and 0.5% bupivacaine and epinephrine in a 50:50 mix (**FIGURE 68.5**). ***Attempts for object removal should first be made with manual digital rectal exam only after imaging has ensured no sharp object is present***. If the object is unable to be removed via digital exam, an anoscope may be inserted to better visualize the object (**FIGURE 68.6**). Ring forceps may then be used in an attempt to remove the object (**FIGURE 68.7**). When attempting manual manipulation, suprapubic pressure may be directed to push the object toward the rectum while the patient performs a Valsalva maneuver.

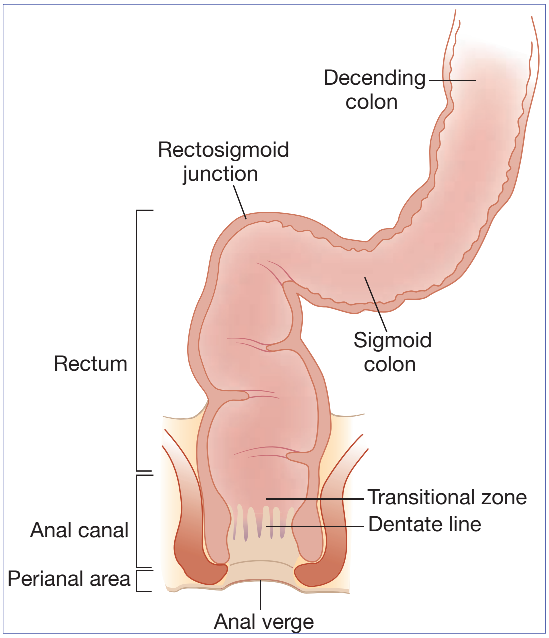

FIGURE 68.4 Objects distal to the rectosigmoid colon are generally amenable to ED retrieval. Frequently, delays in presentation and multiple attempts at self-removal lead to mucosal edema and muscular spasms, which further hinder removal. Rectal lacerations and perforations may occur but are less common than other complications.

Sometimes larger objects may create a vacuum effect. In such cases, it may be necessary to pass a catheter behind the object and inject air into the balloon (**FIGURE 68.8**). This aids in breaking the vacuum seal and may assist in object removal. If the FB still cannot be retrieved, special equipment from the OR, known as *Ferguson* and/or *Pratt retractors*, may be obtained to increase the viewing field of the rectum in terms of width and depth (**FIGURE 68.9**).

Bedside removal of the FB in children is generally avoided. Surgery should be consulted for sedation and removal under anesthesia in most cases.

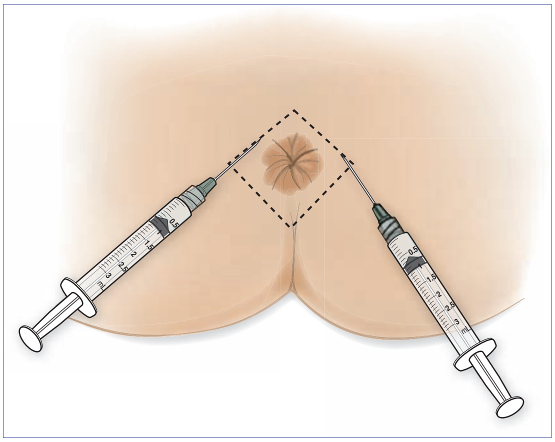

FIGURE 68.5 The perianal block requires that anesthetic be injected first superficially approximately 5 mm around the border of the perianal skin. The anesthetic may then be infiltrated into the intersphincteric space around the rectum, providing anesthesia and relaxation of the external sphincter.

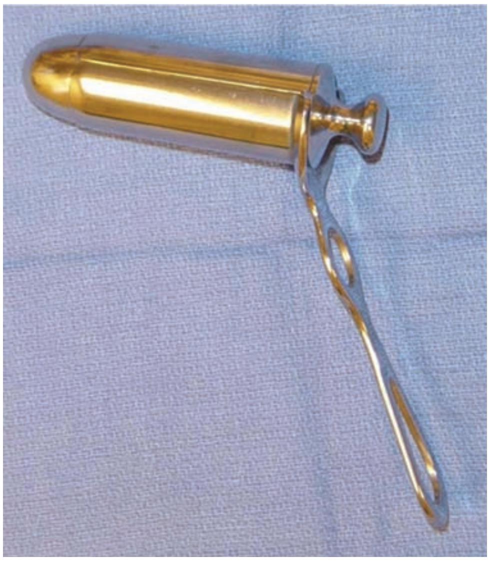

FIGURE 68.6 Anoscope.

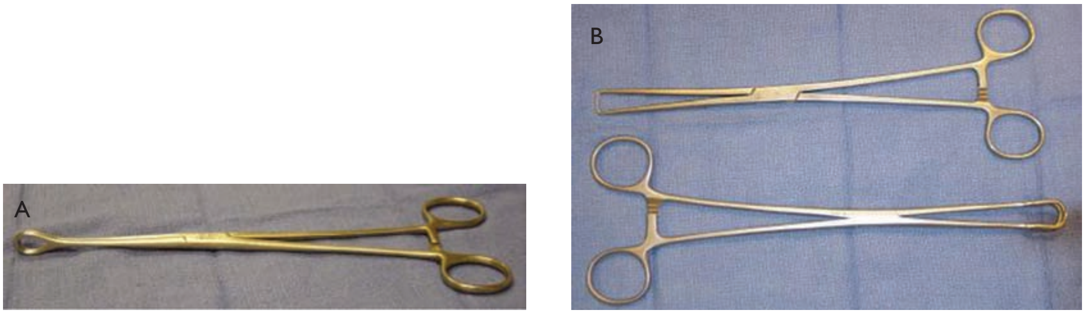

FIGURE 68.7 (A) Ring forceps for retrieving the FB, but only after it is in view. Never blindly use this instrument without a sufficient view of the FB. (B) Tenaculum forceps are better able to grab a ridged object.

FB, foreign body.

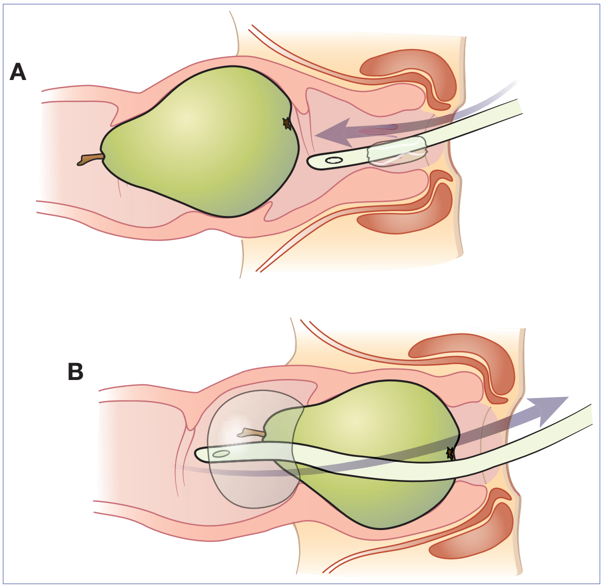

FIGURE 68.8 Rectal FB removed via placement of a Foley catheter. (A) The Foley catheter is inserted distal to the FB and (B) then the balloon is inflated. Gentle traction is applied until the FB can be expelled.

FB, foreign body.

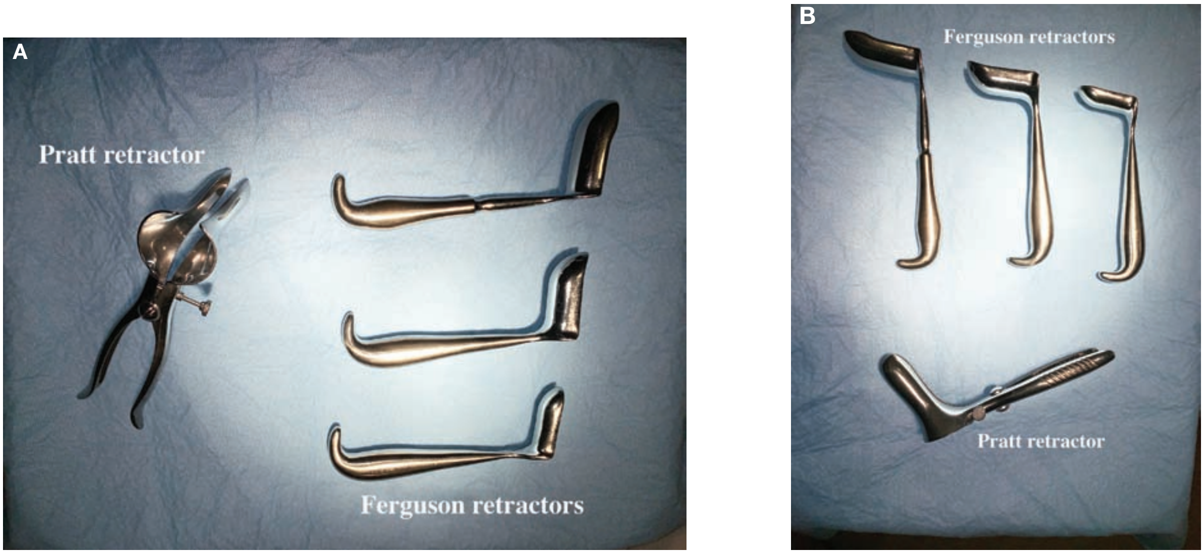

FIGURE 68.9 Pratt retractor seen on the left in image (A) and the bottom of image (B), whereas Ferguson retractors in various sizes are seen on the right of image (A) and top of image (B). These instruments increase the viewing field of the rectum significantly in terms of width and depth and allow ring forceps to be used to view and retrieve rectal FBs.

FB, foreign body.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- ***Any signs of peritonitis or bowel perforation***
- Enemas or stimulant suppositories
  - May cause further injury
- In these cases, surgery should be consulted for object removal in the OR.

SPECIAL CONSIDERATIONS

- Pediatric patients
- Body packers
- Sharp foreign bodies

PROCEDURE PREPARATION

- Ring forceps
- Tenaculum forceps
- Anoscope
- Pratt retractor (if desired)
- Ferguson retractor
- Foley catheter
- Water-based lubricant

PROCEDURE

- Standard precautions should always be followed.
- Make sure lighting is appropriate.
- Place patient in the proper position:
  - Knee to chest
  - Lithotomy
    - Patient on back with the hips and knees flexed and the thighs apart
  - Sims
    - Left lateral decubitus
- Using gloves, first inspect the exterior anus.
  - If the object can be viewed, lubricant may be applied to the anal canal and an attempt may be made to remove the object via digital exam.
- If the object cannot be removed, an anoscope may be used to better visualize the object.
- After appropriate lubrication with visualization of the object, ring forceps may be used in an attempt to remove the object.
- If the object still cannot be removed, a vacuum seal may be present.
  - In such cases, pass a Foley catheter past the object.
  - Inflate the catheter.
  - Retrieve the Foley catheter and FB via slow, constant, and gentle traction.
- If the object still cannot be removed, insert either the Pratt or Ferguson retractor to increase the viewing field (**FIGURE 68.10**).
  - If the FB can be visualized, use ring forceps to grasp and retrieve the FB.
  - ***Never insert ring forceps blindly in the rectum.***
- Perform urethral or vaginal culture, wet prep, and DNA probe for gonorrhea and chlamydia if there is any suspicion of sexual abuse.

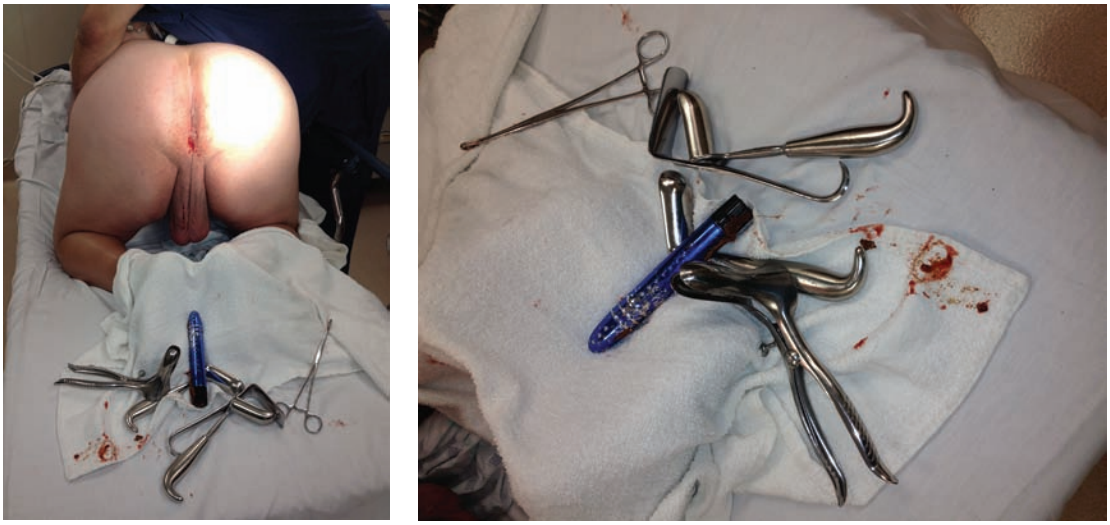

FIGURE 68.10 With the use of sedation and analgesia, a Pratt retractor, various sizes of Ferguson retractors, and ring forceps, a vibrator was removed as a rectal foreign body. Such retractors are not standardly stocked in EDs but are readily available in the operating room. Proper positioning (knee to chest in photo), sedation, and analgesia are required. *Note*: Applying suprapubic pressure or having patient perform Valsalva maneuver may be helpful when objects are difficult to remove with this method.

POSTPROCEDURE CONSIDERATIONS

Assessment of the rectal sphincter should be performed after any attempt at object removal. Postprocedure proctoscopy or flexible sigmoidoscopy is also recommended to evaluate for internal injuries. It is important to observe the patient several hours postprocedure for any signs of bowel perforation. If sphincter damage or if signs of peritonitis occur, the surgical team should be consulted.

EDUCATIONAL POINTS

- Advise the patient to return to the clinic if pain, bleeding, constipation, or fever develops.
- Patient should be advised upon discharge that if abdominal pain, hematochezia, constipation, or fever develops, they should return to the ED.
- Patient should be instructed to follow up with their primary care provider (PCP) postdischarge.
- In cases for which there is concern over psychiatric illness, follow-up with a psychiatrist should be offered.

COMPLICATIONS

- Tearing of the rectal mucosa
- Bowel perforation
- Rectal sphincter insufficiency
- Ischemia
- Infection
- Postprocedure bleeding

PEARLS

- Body packing raises concerns over rupture of the drug packet and exposure of the patient to its contents (e.g., heroin or cocaine toxicity).
- Adequate sedation and analgesia are critical prior to attempting object removal, as anal spasm and patient discomfort may hinder object visualization and exposure.
- Presentation is almost always delayed because of embarrassment.
- Abdominal x-ray and/or abdominal/pelvis CT should be performed prior to digital rectal exam to avoid provider injury.
- Surgery should be consulted in any of the following situations:
  - If signs of peritonitis develop at any time
  - Object is sharp or cannot be removed
  - Rectal tone becomes diminished
- Avoid enemas and bowel stimulants as they may push the foreign body more proximally and may cause more extensive rectal-wall injury.

VAGINAL FOREIGN BODIES

BACKGROUND

Although the diagnosis of vaginal FB is often obvious in the adult patient, who will frequently self-report, this diagnosis may not be as obvious in children and should be considered when a pediatric patient presents with vaginal bleeding or discharge (particularly if malodorous or persistent). Less common, patients may present with genital itching, genital erythema, dysuria, or pain. The most frequently implicated vaginal FBs in children include pieces of toilet paper and jewelry. In adults, they include (**FIGURE 68.11**)

- Condoms
- Tampons
- Sexual toys
  - Vibrators
  - Sexually stimulating beads
  - Massage devices
- Coins
- Toys
- Pessaries
- Menstrual cups
- Drug packets

Important factors to consider when evaluating a patient with a vaginal FB include duration and recurrence of symptoms, intentional versus accidental insertion, and by whom the object was inserted. FBs that have been retained in the vagina for a long period of time can lead to secondary infection, become embedded in the vaginal wall, and can rarely lead to the formation of vesicovaginal or rectovaginal fistulas. ***Sexual abuse should be considered in all children who present with vaginal FBs, particularly if the behavior is recurrent***. Psychiatric illness should also be considered (**FIGURE 68.11**).

The average vagina is about 8 cm in length, but with sexual arousal can expand almost 200%. Like the stomach, the vagina has rugae. The vagina is situated partly in the pelvic cavity and partly in the perineum. The posterior fornix, which is the deepest aspect, is related to the recto uterine pouch and one must be cognizant to inspect this deepest area in regard to a possible FB (**FIGURE 68.12**).

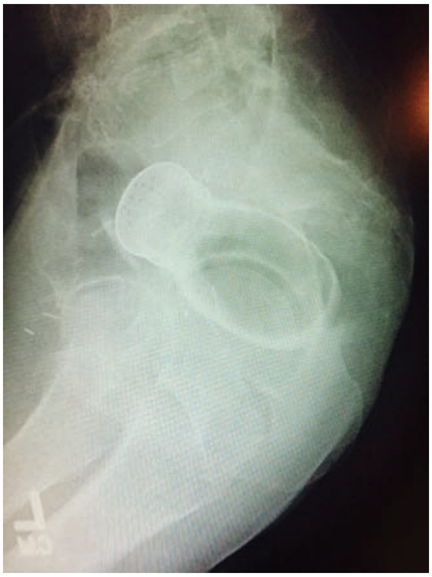

FIGURE 68.11 Salt shaker as vaginal FB. FB, foreign body.

Clinical examination of a suspected vaginal FB includes careful speculum and digital examination, in that order, considering the possibility of the presence of a sharp object, especially in the psychiatric patient. In pediatric patients, transabdominal ultrasound can be helpful in the initial evaluation, alongside direct visualization utilizing a pediatric speculum or nasal speculum. Flat-plate abdominal x-ray can help identify radio-opaque objects (**see FIGURE 68.11**). Rarely, CT scan or MRI may be necessary to identify involvement of other organs and complications such as abscesses and fistulas.

PATIENT PRESENTATION

- Bloody vaginal discharge or vaginal bleeding
  - Most common presenting symptom
- Malodorous or nonspecific vaginal discharge
- Vaginal itching or erythema
- Dysuria
- Abdominal or vaginal pain
- Symptoms may be nonspecific in pediatric patients

TREATMENT

In adults, most objects may be visualized under vaginal speculum examination and removed with ring forceps. A weighted vaginal speculum allows a much larger viewing area in cases that need this (**FIGURE 68.13**). Smaller objects that cannot be grasped with ring forceps may be removed with warm-water vaginal lavage. Air insufflation, using a Foley catheter inserted vaginally alongside an FB to break the suction, while gently providing traction on the object, may facilitate removal (**FIGURE 68.14**). Placing an examining finger in the rectum and applying gentle pressure on the posterior vaginal wall may facilitate expulsion. If encountering difficulty with object removal (e.g., with large objects), removal under sedation or general anesthesia may be required.

In children, warm-water vaginal lavage may be attempted after an FB is visualized. Digital and ring forceps removal may also be attempted. If more invasive techniques are required or in the very young, consider sedation and removal under anesthesia.

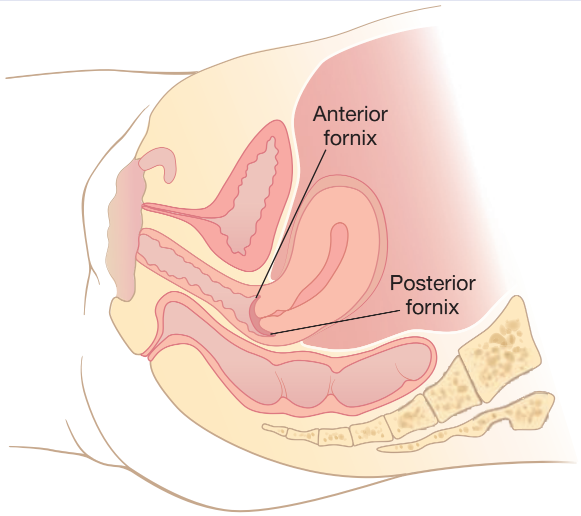

FIGURE 68.12 Vagina. Note the deepest structure, the posterior fornix (there is also an anterior as well as two lateral fornixes).

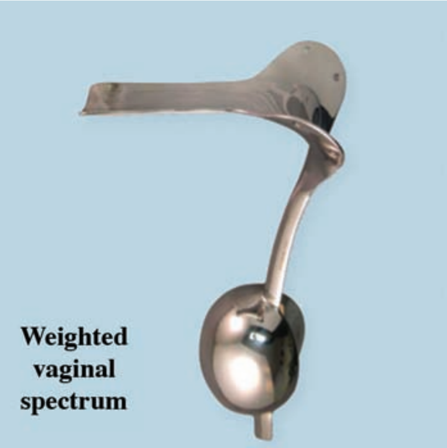

FIGURE 68.13 Weighted vaginal speculum. Allows a robust view of the vagina. Such retractors are not standardly stocked in EDs but are readily available in the operating room.

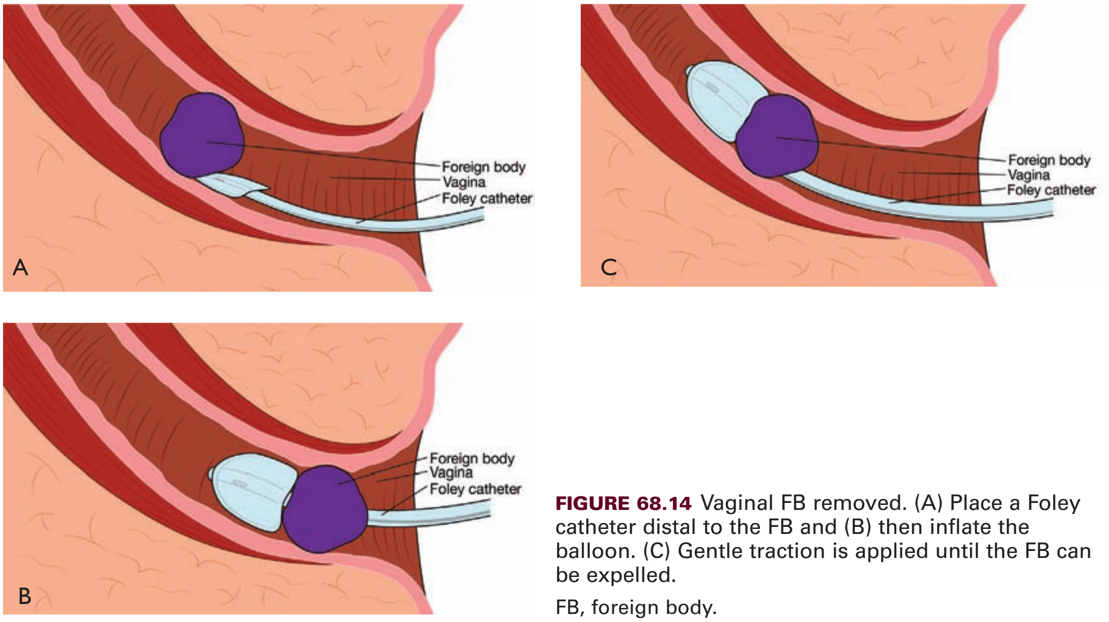

FIGURE 68.14 Vaginal FB removed. (A) Place a Foley catheter distal to the FB and (B) then inflate the balloon. (C) Gentle traction is applied until the FB can be expelled.

FB, foreign body.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Do not attempt removal of embedded objects, as bleeding or perforation can occur.

SPECIAL CONSIDERATIONS

If sexual abuse is suspected, file a report to Child Protective Services. A sexual abuse assessment may be necessary, which includes a forensic interview and anogenital examination by a skilled child abuse healthcare provider. Cultures for gonorrhea and chlamydia should be obtained in all pediatric patients with vaginal foreign bodies, as a positive test may be the only indication of sexual abuse.

PROCEDURE PREPARATION

- Ring forceps
- Vaginal speculum
    - A weighted vaginal speculum may be used for enhanced viewing.
    - In pediatric patients, a nasal speculum may also be necessary.
- Culturette swab
- Foley catheter
- 30-mL syringe

PROCEDURE

- Standard precautions should be followed at all times.
- Place adults and adolescents in the dorsal lithotomy position, and children and infants in the frog-leg position.
- Ensure adequate lighting.
- Examine external genitalia by holding labial traction and separation to open the hymen.
- Perform vaginal or nasal speculum examination.
- Most objects may be grasped and removed using ring forceps or fingers.
- Small debris may be removed using a Foley catheter placed vaginally. Connect it to a 30-mL syringe filled with warm water and perform gentle vaginal lavage.
- Larger objects can be removed by hand with added viewing area provided by a weighted speculum.
- Provide air insufflation by utilizing a Foley catheter inserted vaginally alongside a foreign object to break the suction while gently providing traction on the object; this may facilitate removal. The balloon may be inflated to provide direct traction on the object.

- Gentle compression of the vaginal wall during a rectal examination may aid in expulsion of the foreign object.
- Perform vaginal culture, wet prep, and DNA probe for gonorrhea and chlamydia if secondary infection is suspected, and in all pediatric patients.

ULTRASOUND GUIDANCE

Point-of-care ultrasound (POCUS) can be particularly helpful in diagnosing vaginal FBs, especially in pediatric patients, as it is a pain-and-radiation-free modality. Either the curvilinear or linear transducers may be used to obtain a transabdominal view. A moderately to fully distended bladder should be present to serve as an "acoustic window" for the visualization of more posterior structures. As always, diagnostic accuracy may be affected by sonographer experience and skill.

Yang, Sun, Ye, Li, and Tao (2017) retrospectively studied 249 females with the diagnosis of a vaginal FB. They found the following:

	POCUS	X-RAY
Sensitivity	81%	24%
Specificity	53%	91%
PPV	82%	88%
NPV	51%	31%

NPV, negative predictive value; PPV, positive predictive value.

Other significant findings of this study include:

- For those FBs larger than 5 mm, the rate of sonographic accuracy reached 100%.
- Of FBs, 77% were less than 2 cm from the vaginal orifice.
- All FBs were hyperechoic compared with adjacent tissues.
- All patients had a full recovery except one who had vaginal ulceration secondary to a retained battery.

Gross and Riera (2017) described the removal of a pen vaginal FB in an 11-year-old patient. After pen removal, there was concern with regard to a pen cap. Using POCUS, they identified the pen cap still residing in the vagina, after which it was successfully removed (**FIGURE 68.15**).

The transabdominal exam should include both sagittal and longitudinal views. The vaginal stripe is more easily visualized in the sagittal view, as it will appear as an echogenic line. Foreign bodies will likely be more dense, and thus hyperechoic (bright), in comparison to the surrounding tissues (**FIGURE 68.15**). Metal and glass may cause reverberation or "comet tail" artifact; plastic, cotton, and wood may cause acoustic shadowing; and tissue paper causes no acoustic shadowing. The acoustic shadowing can, unfortunately, be similar in appearance to that of intestinal gas. In contrast to

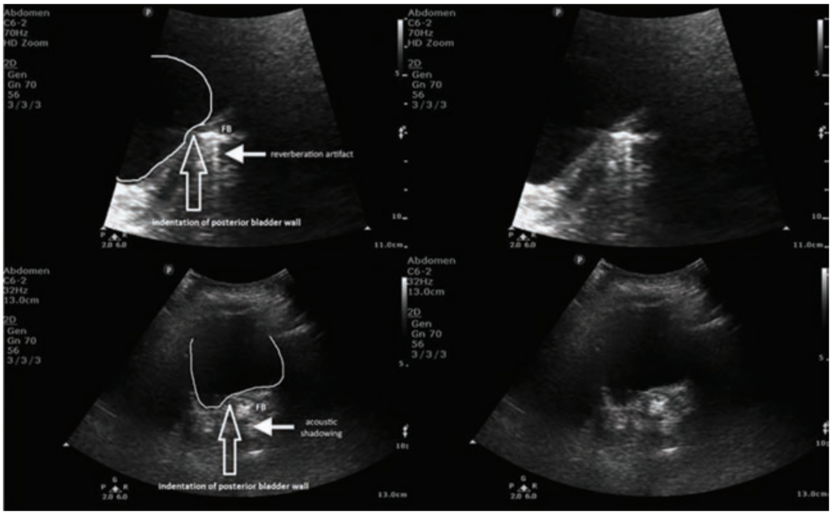
FB
reverberation artifact
indentation of posterior bladder wall
FB
acoustic shadowing
indentation of posterior bladder wall

FIGURE 68.15 Transabdominal exam in sagittal view demonstrating indentation of the bladder wall. (*Top*) Reverberation artifact is seen behind a foreign body. (*Bottom*) Acoustic shadowing is seen behind a foreign body.

Source: Courtesy of Isabel Theresia Gross, MD, PhD, MPH and Antonio Riera, MD, FAAP; Yale University School of Medicine.

intestinal gas, though, foreign bodies do not generally change in shape, size, or location with changes in pressure. A foreign body that is close to the bladder may also cause an indentation in the bladder wall.

POSTPROCEDURE CONSIDERATION

Antibiotics are not typically necessary following the removal of the FB.

EDUCATIONAL POINTS

- Advise the patient to return to the clinic if pain, bleeding, or fever develops.
- Discourage the use of douching.
- Instruct the patient to follow up with her pediatrician/primary care provider in a specified amount of time.
- Children younger than 7 years old or uncooperative patients may require vaginoscopy in the OR with anesthesia.

COMPLICATIONS

- Urinary tract infection
- Vaginal infection
- Toxic shock syndrome
- Vaginal fistula
- Abdominal or pelvic abscess
- Perforation

PEARLS

- A Foley catheter may be inserted vaginally alongside a foreign object to break the suction, allowing for easier and less traumatic removal of the object.
- A weighted speculum can be used to enhance the view.
- Active or passive increases in the intra-abdominal/pelvic pressure may aid in the removal of the foreign object.
- A vaginal FB in a pediatric patient is sexual abuse until proven otherwise.

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UNIT
XVI

Miscellaneous Procedures

CHAPTER
69

Procedures for Performing Skin Biopsy

Mary C. Kamienski

BACKGROUND

A biopsy is performed to diagnose or rule out skin pathology and some medical conditions. Often it is done to confirm a clinical diagnosis or to guide appropriate treatment. An old axiom in dermatology is that there are only two times when a biopsy should be obtained: (a) when you believe a biopsy is needed and (b) when you believe a biopsy is not needed. In other words, the information gained from a biopsy is almost always useful, and therefore a biopsy is often warranted.

Determining the usefulness of skin biopsy should include consideration of the following:

- **Stability of the lesion.** Stable lesions are not new and have not changed in morphology (shape) or color. The ABCDE (asymmetry, border, color, diameter, evolution) criteria can be used to determine what lesions are suspicious for melanoma or other malignancies. The Glasgow 7-point checklist (change in size, change in shape, change in color, diameter >7 mm, inflammation, crusting or bleeding, sensory change) and the "ugly duckling" sign (i.e., one lesion that is distinct from others) can also be used to identify suspicious lesions requiring biopsy.
- **Location of the lesion.** Choosing a site for a biopsy of a rash or another expanding/diffuse lesion is influenced by the location of the lesion. If there is an expanding edge, a biopsy of this area typically offers the most helpful results. A biopsy of the inner aspect of such a lesion will often only show necrotic cells or otherwise give an inaccurate reflection of the true pathology. **FIGURE 69.1** demonstrates the appropriate location for the biopsy along the expanding edge.
- **Timing of the biopsy**. With inflammatory skin lesions, it is almost always preferable to biopsy a new or recent lesion. If the patient's rash is long-standing, with no lesions less than 2 weeks old, a biopsy would be of dubious benefit. A better plan would be to have the patient return when new lesions occur. A biopsy of a lesion within 48 hours of onset will give the best representative pathology and clues for diagnosis. Evolving processes can be biopsied as long as there are newer lesions present. If malignancy is suspected, a biopsy can be done at any time.
- **Location of biopsy**. The location of a needed biopsy is another important consideration. Depending on the location, the risks may outweigh the benefits, or at a minimum require specialty consultation. For example, a biopsy done on the foot of a patient with diabetes presents a high risk of complications such as cellulitis or a nonhealing wound. Other areas sensitive to biopsy are the face, hands, and genitalia.

The importance of the interpretation of the biopsy cannot be underrated. There are many subtleties of reading a biopsy that can be easily overlooked by someone without sufficient expertise. Proper pathologic diagnosis by a dermatopathologist is essential to provide the best evaluation and diagnosis of the biopsy. The report should include a detailed microscopic description with interpretation framed in the language of clinical dermatology.

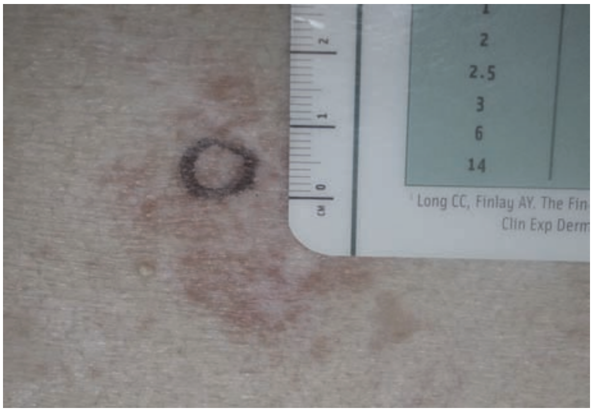

FIGURE 69.1 Lesion for biopsy.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- History of diabetes, bleeding disorders, or excessive bleeding after other surgical procedures
- Immunosuppression
- Current infection at the site

SPECIAL CONSIDERATIONS

- Children often cannot cooperate and sedation may be considered.
- Various methods can be used to perform skin biopsies, including shave, punch, and incisional techniques.
    - Choosing the appropriate method will depend upon how much tissue is necessary to obtain an accurate diagnosis while causing the least obvious cosmetic defect.

SHAVE BIOPSY

BACKGROUND

A commonly used technique in biopsying the skin is the shave biopsy. This is performed with a straight-edge razor using a sterile scalpel blade to shallowly remove a thin disk. Shave biopsies are used for lesions that are thin and spread over a large area. A small pedunculated lesion is ideal for a shave biopsy, whereas a lesion flatter or deeper in the skin (e.g., subcutaneous lesion, nevi, or pigmented lesion) would require more skin removal and lead to more scarring. One of the advantages of a shave biopsy is that it is easier to maintain hemostasis. This is especially helpful in patients who are anticoagulated. Close monitoring for keloid formation following the biopsy is needed in areas that are more prone to keloid scarring (e.g., bony prominences such as the sternum, elbows, and shoulders).

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Location (central face, shin, sternum, or bony prominence)
    - Flat, deep lesions
    - Skin appendage lesions
    - Epidermal nevi

PROCEDURE PREPARATION

- Electrocautery device
- Sterile scalpel blade
- Skin-cleanser prep
- Lidocaine 1% or 2% without epinephrine
- Syringe
- Small-gauge needle (30 gauge)
- Formaldehyde with specimen cup
- Bandage

PROCEDURE

- Prepare the area using a skin cleanser.
- Anesthetize the designated area using lidocaine. To avoid distortion due to vasoconstriction, lidocaine with epinephrine is generally avoided for these smaller biopsies.
- Using a sterile scalpel blade and scooping technique, remove a layer of the skin. Care must be used to not go too deep or remain too shallow.
- Removing a portion of approximate depth of 1 mm is usually sufficient.
    - Place specimen in the formaldehyde cup.
- Cauterize using electrocautery, chemical cautery (aluminum chloride or ferrous sulfate), or heat cautery.
- Apply a bandage.

POSTPROCEDURE CONSIDERATIONS

- Bleeding
  - Apply pressure to minimize bleeding and bruising to the area.

EDUCATIONAL POINTS

- A No. 15 scalpel blade held horizontally in the hand can provide good control of depth.
  - Cautery method should be determined prior to procedure. If the patient is anticoagulated, there will be more bleeding. Generally, if a patient has a pacemaker or a defibrillator do not use electrocautery; substitute chemical or heat cautery.
- Cautery using ferrous sulfate: Caution must also be used if using chemical cautery with ferrous sulfate. The iron element in the cautery will commonly “stain” or tattoo the biopsy site, even after healing. Therefore, it should only be used as needed and avoided entirely on the face or other cosmetically sensitive areas.
- Heat cautery: Caution also needs to be used when using heat. Unlike electrocautery, heat cautery can easily burn through a glove, injuring the caregiver or destroying tissue deeper in the skin.

COMPLICATIONS

- Bleeding
- Pain
- Infection
- Allergic reaction to topical antibiotic if used
- Scarring

PUNCH BIOPSY

BACKGROUND

If the suspected diagnosis is likely to include deep dermis or subcutaneous tissue, a punch biopsy should be used to obtain a deeper specimen. A circular cutting instrument much like a hole puncher (called a trephine) is used to make a hole at a predetermined size (available in 2–10 mm sizes). Although 4 mm is the standard size of a punch biopsy specimen, the size should be adjusted to the area of concern. Smaller sizes are appropriate on the face and other sensitive areas. The punch biopsy technique has the advantage of obtaining a specimen that extends to the level of fat and enables identification of diseases such as sarcoidosis and granuloma annulare. Punch biopsies tend to produce a round and slightly depressed scar.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Immunosuppression
- Anticoagulants (i.e., warfarin, clopidogrel)

SPECIAL CONSIDERATION

- Diabetes

PROCEDURE PREPARATION

- 4-mm punch
- Electrocautery device
- Skin-cleanser prep
- Lidocaine 1% or 2% without epinephrine
- Syringe

- Small-gauge needle (30 gauge)
- Forceps
- Formaldehyde with specimen cup
- Pressure dressing material
- Nonabsorbable suture material
- Suture kit (usually 4-0 for trunk and extremities, 5-0 for neck and other more delicate areas, and 6-0 for the face)

PROCEDURE

- Prepare the area using a skin cleanser.
- Anesthetize the designated area using lidocaine. Lidocaine with epinephrine is generally avoided for these smaller biopsies.
- The punch is then applied to the skin with a single, clockwise twisting motion (**FIGURE 69.2**).
    - It is important not to reverse direction as in a washing-machine motion, but to keep twisting in one direction.
    - This one motion will help to prevent shearing forces that can separate the layers of the skin, creating artifacts that will make analysis by the pathologist much more difficult.
    - One of the most common mistakes is to puncture only to the dermis. Generally, a puncture through the dermis into the subcutaneous fat is needed to allow evaluation of the skin's full thickness (epidermis, dermis, and the subcutaneous layer). Obtaining each of these layers is crucial for an accurate pathology report.
- After a sufficiently deep biopsy is achieved, the specimen should be maneuvered with a needle to gently elevate the specimen above the skin to allow cutting the subcutis attachment (**FIGURE 69.3**).
    - If forceps or pickups are used to grab the tissue, a "crush" artifact can be created, rendering the specimen uninterpretable.
    - If small, single-tooth forceps are used and the tissue is handled gently, this crush artifact is generally avoided. The tissue is easier to handle this way than with a needle.
- The biopsy should be immediately placed in formaldehyde for transfer to the pathology laboratory.
- Hemostasis is normally not needed for a 4-mm punch. The biopsy site can be cauterized if needed, and the defect closed with an appropriately sized nonabsorbent suture.
- Apply a bandage to the wound.

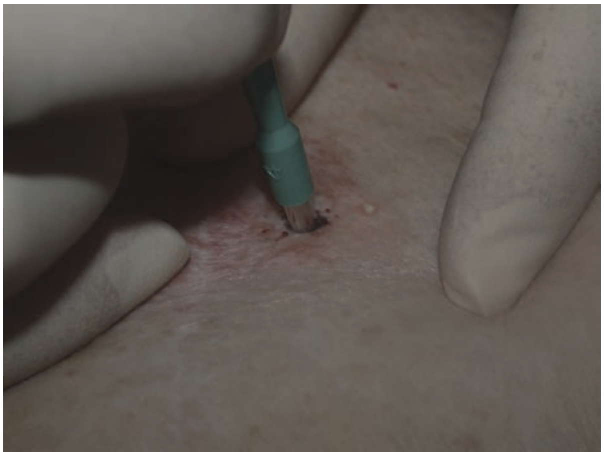

FIGURE 69.2 Performing a punch biopsy.

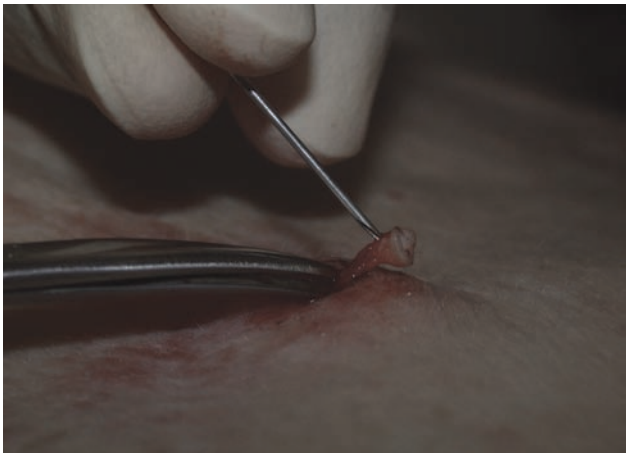

FIGURE 69.3 Maneuvering a punch biopsy specimen.

POSTPROCEDURE CONSIDERATIONS

- Bleeding
- Pain

EDUCATIONAL POINTS

- Depending on the location, the sutures are removed after a suitable time.
    - Face: remove after 5 to 7 days
    - Scalp, neck, and arms: after 8 to 10 days
    - Trunk: after 10 to 12 days; leg—14 days

COMPLICATIONS

- Bleeding
- Scarring, which may lead to keloid formation

INCISIONAL BIOPSY

BACKGROUND

This type of biopsy is used for a larger lesion, one that is suspicious of metastatic potential, or a lesion that necessitates the procurement of subcutaneous fat. This biopsy can also be called a “wedge” biopsy as it will be used to obtain a full thickness of tissue through the dermis into the subcutaneous tissue, down to muscle.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

- Immunosuppression
- Anticoagulants (i.e., warfarin, clopidogrel)

SPECIAL CONSIDERATION

- Diabetes

PROCEDURE PREPARATION

- Lidocaine 1% or 2% (with or without epinephrine)
- Suture material (nonabsorbable and absorbable; 4-0, 5-0, or 6-0)
- Pickups
- Scalpel (No. 11 or No. 15 blade)
- Skin hook
- Hemostat
- Electrocautery device
- Gauze
- A hydrocolloid, moisture-retentive dressing or other dressing
- Sterile drape

PROCEDURE

- Prepare the area using a skin cleanser and drape the patient.
    - This biopsy should be performed under sterile conditions.
- Anesthetize the surrounding skin with lidocaine alone or lidocaine with epinephrine.
    - If lidocaine with epinephrine is used, wait 15 to 20 minutes before beginning the procedure to allow the epinephrine to constrict blood vessels.

- Incise the area and then remove the necessary tissue.
- Ensure hemostasis by using electrocautery or heat cautery to any bleeding following the excision.
- Deep sutures are placed using absorbable suture through the papillary dermis. These sutures provide most of the strength and also need to be used to approximate the closure. A subcuticular suture may be used, although the long-term cosmetic results may be inferior to other methods of closure.
- Place skin sutures to approximate the skin, allowing the best cosmetic result. Nonabsorbent sutures are used most often (e.g., prolene or another synthetic monofilament).
- Apply a bandage to the wound.

POSTPROCEDURE CONSIDERATION

- Antibiotics are not routinely needed for larger excisions performed under sterile procedure. However, depending on the patient risk factors and location of the biopsy, prophylactic coverage may be warranted.

COMPLICATIONS

- Pain
- Bleeding
- Infection

PEARLS

- A fine, single-tooth forceps can be used in place of skin hooks to help prevent stick injuries in those who are not used to handling skin hooks.
    - The correct biopsy to use for melanoma is controversial. The type of biopsy does not negatively influence melanoma survival rates.
    - Pediatric patients tend to heal well and faster than adult patients.

RESOURCES

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CHAPTER

70

Procedures for Performing Lumbar Puncture

Erik C. Ridgway and Keith Lafferty

BACKGROUND

As far back as the late 1800s, the subarachnoid space (SAS) was used for spinal anesthesia via cocaine, and shortly after, diagnostic needle sampling of cerebrospinal fluid (CSF) ensued. Current indications for performing a lumbar puncture (LP) are for the diagnosis of meningitis and possibly subarachnoid hemorrhage (SAH), both of which have time-sensitive treatment-based high morbidities and mortalities. Clinicians must not let their guard down, as 4% of all ED chief complaints involve cephalgia. One must always think "worse first" and entertain these two potentially devastating disease states.

Because neuronal tissue itself contains no pain fibers, the suspicion of cephalgia arises from pain in the following structures:

- Scalp (skin, muscle)
- Dura (especially at the base of the brain)
- Venous sinuses
- Meningeal arteries
- Cranial nerves (CNs) V, VII, and IX
- Periosteum

Meningitis

Although it is beyond the scope of this book to go into great detail about the etiology and treatment of meningitis, certain points need to be made. The epidemiology of bacterial meningitis has shifted from a disease of the very young to a disease of adults. For example, the median age for persons with bacterial meningitis in the United States was 15 months in 1986, 25 years in 1998, and 39 years of age in 2007. A population-based survey revealed that incidence of bacterial meningitis directly correlates with increasing age, with the elderly population (65 years of age and older) being at highest risk.

Meningitis caused by *Haemophilus influenzae* type b (Hib) has been nearly eliminated in the Western world since vaccination against Hib was initiated in the 1980s, which explains why rates of meningitis have decreased in young children. Likewise, the introduction of conjugate vaccines against *Streptococcus pneumoniae* is expected to reduce the burden of childhood pneumococcal meningitis significantly, as the vaccine has been shown to have a 97.4% efficacy rate. Although inoculation with a pneumococcal conjugate vaccine is producing herd immunity (increasing immunization is decreasing incidence of the disease and indirectly protecting unimmunized people) among adults, the age distribution of meningitis has now shifted to older age groups who are not routinely immunized until age 65. The incidence of bacterial meningitis in adults now directly correlates with increasing age, with the elderly population (65 years of age and older) being at highest risk. Vaccines are also responsible for the falling prevalence of meningococcal disease in the United States. Recipients of the vaccination develop antibodies against the four

Visit https://connect.springerpub.com/content/reference-book/978-0-8261-8512-9/toc-part/ch00 to access the videos in this chapter.

major strains that are responsible for 82% of meningococcal disease. Rates of neonatal *Streptococcus agalactiae*, also known as group B *Streptococcus* (GBS), meningitis have also decreased because of routine testing of pregnant women for GBS (25% carrier rate) with prompt treatment via appropriate antibiotics during labor.

Although specific antibiotics for treatment of meningitis are beyond the scope of this book, the clinician needs to administer appropriate antimicrobials pertaining to the patient's age in the most expeditious manner possible, ideally before the LP is performed.

In a prospective study (van de Beek et al., 2004) of 696 patients with proven bacterial meningitis, the patients showed the following common signs, symptoms, and etiology of meningitis:

- Classic triad of fever, altered sensorium, and neck stiffness occurred only in a minority of patients, 44% overall
- Headache (HA)—87%
- Neck stiffness—83%
- Altered sensorium—69%
- Focal neurological deficit—14%
- Seizure—5%

Bacterial and viral etiologies have similar presentations (HA, fever, and stiff neck); however, viral meningitis is associated with an extremely low morbidity rate and most recover fully in 7 to 10 days (the exception is herpes simplex virus [HSV]). On the contrary, the high morbidity and mortality associated with bacterial meningitis can be catastrophic and cannot be understated.

Viral Meningitis

- No treatment is generally the rule.
- Most cases are diagnosed (LP) and treated as if bacterial until cultures are negative; empiric antibiotic therapy is often selected pending CSF studies.
- HSV is an important cause of meningitis and encephalitis (inflammation of the brain), which presents with characteristics similar to viral meningitis, coupled with an altered mental status, and is treated with antiviral therapy.

Bacterial Meningitis

- Aggressive treatment is key.
  - Untreated bacterial meningitis can lead to high morbidity and/or death in a few hours.
  - Of those who survive invasive meningococcal disease, 10% to 20% experience sequelae, including limb loss from gangrene, extensive skin scarring, or diffuse cerebral infarction.
  - Patients with meningococcal meningitis who do not develop septic shock are less likely to die or experience these sequelae, but are at risk of developing neurosensory hearing loss, mild to moderate cognitive defects, or seizure disorders.
  - Prior to the 1985 implementation of the Hib vaccine, meningitis occurred in approximately two-thirds of children with invasive Hib disease, displaying the virulence of *Haemophilus influenzae* while also displaying high morbidity with those fortunate enough to survive. Of survivors, 15% to 30% developed hearing impairment or severe permanent neurologic sequelae, such as mental retardation, seizure disorder, cognitive and developmental delay, and paralysis. Please see **TABLES 70.1** and **70.2** for specific age and epidemiologic factors including mode of transmission, prevalence, and presentation based on the type of organism.

Procalcitonin

Procalcitonin (PCT), an acute-phase reactant, has been shown to be highly accurate and specific in the differentiation between viral and bacterial illness (Ko et al., 2017). This distinction is preserved even in light of underlying inflammatory autoimmune diseases (Wu et al., 2012). PCT has become an increasingly accepted marker in the early detection of bacterial illness. Although the bulk of PCT research has focused on antibiotic stewardship and mitigation of unnecessary antibiotic administration for respiratory tract and urinary tract infections, current literature suggests a possible role in the differentiation, diagnosis, and treatment of meningitis.

TABLE 70.1 Meningitis Prevalence, Presentation, and Mode of Transmission Based on the Type of Organism

Organism	US Prevalence (Adults)	Presentation	Transmission
Streptococcus pneumoniae	**71% *(most common bacterial infection)*** HIV *Most common community-acquired cause*	58% (classic triad) Highest incidence *<2 years* *>65 years*	**Airborne droplets**
Neisseria meningitidis	**12%**; can occur in epidemics but 98% of cases are sporadic	27% (classic triad) Petechial nonblanching rash in 60%	**Airborne droplets** **Salivia/secretions** Crowded living conditions can facilitate transmission (e.g., college dormitories) Carriers ■ 5%–10% of adults are carriers in nasopharynx ■ Few develop invasive disease
Hib	**6%** *(adults)*	Most common cause of meningitis in children < 5 years	**Airborne droplets**
GBS	**7%**	Neonates less than 3 months 60% Elderly	**Vaginal delivery** offers *30-fold reduction of neonatal GBS with intrapartum antibiotics in pregnant carriers* Infection
Listeria monocytogenes	**4%**	Alcoholics Elderly Pregnant	**Food borne** *Eating contaminated unpasteurized dairy, produce, or deli meats*

GBS, Group B *Streptococcus*; Hib, *Haemophilus influenzae* type b.

Source: Thigpen, M. C., Whitney, C. G., Messonnier, N. E., Zell, E. R., Lynfield, R., Hadler, J. L., … Schuchat, A. (2011). Bacterial meningitis in the United States, 1998–2007. *New England Journal of Medicine, 364*(21), 2016–2025. https://doi.org/10.1056/NEJMoa1005384

TABLE 70.2 Bacterial Meningitis Epidemiology by Age Group

Newborn	Infants and Children	Young Adults	Adults and Elderly
GBS *Streptococcus pneumoniae* *Listeria monocytogenes* *Escherichia coli*	***S. pneumoniae*** *Neisseria meningitidis* Hib GBS	***N. meningitidis*** *S. pneumoniae*	***S. pneumoniae*** *N. meningitidis* Hib GBS *L. monocytogenes*

GBS, Group B *Streptococcus*; Hib, *Haemophilus influenzae* type b.

Bacterial meningitis is a feared diagnosis that must be emergently treated or effectively ruled-out in a timely manner given its fulminant course, which is associated with devastating morbidity and mortality. This is at the top of the list of “can’t miss” diagnoses for clinicians. Although the discussion is beyond the scope of this book, the perfect rule-out test has a high sensitivity for detection, a high negative predictive value (probability that a patient with a negative result truly does not have the disease), and a low negative likelihood ratio (<1; probability that a negative result will inaccurately occur in a patient with the disease). Current literature supports that an elevated serum PCT level strongly suggests bacterial infection, and PCT is better at identifying serious bacterial infection than serum leukocytes and other acute-phase reactants, such as C-reactive protein. A 2016 meta-analysis of 616 patients concluded that serum PCT is a highly accurate and rapid way to discriminate between viral and bacterial meningitis in children, with 96% sensitivity and a negative likelihood ratio of 0.08 (Henry et al., 2016). A 2016 meta-analysis of 22 studies involving over 2,000 patients revealed that serum PCT exhibited a 95% sensitivity and 97% specificity in the detection of bacterial meningitis (Wei et al., 2016). More recent studies reveal that negative predictive values with a low PCT level exceed 90% for bacterial illness (Levine, Tran, Shepherd, & Naut, 2018).

A more recent and extensive literature review by Velissaris et al. (2018) has shown that a significant body of evidence exists in support of serum PCT as a useful biomarker in the assessment of patients with undifferentiated meningitis. Their review echoed previous studies in that although the data on CSF PCT levels are limited, serum PCT appears to be a useful tool in the evaluation of patients with a known or suspected central nervous system (CNS) infection and may help distinguish between bacterial and viral meningitis. Similarly, a more recent meta-analysis published by Vikse et al. (2015) showed that PCT has a 90% sensitivity and a 98% specificity in the discrimination between bacterial and viral meningitis.

Even when lumbar puncture is performed for diagnostic evaluation in suspected meningitis, PCT still plays a strategic role as CSF testing has known limitations. CSF Gram-staining has demonstrated low sensitivity, cultures require time for growth, and results may be skewed by previous antibiotic treatment (van de Beek et al., 2010). PCT may also prove useful in the prediction of disease severity, morbidity, and mortality. Correlation between the degree of serum PCT level and severity of outcome from bacterial meningitis is suggested by a 2017 study (Ko et al., 2017).

Combined with pretest probability, clinical picture, and clinician gestalt, PCT may be a powerful adjunct to rapidly and accurately distinguishing viral from bacterial meningitis. The process of combining the preceding factors (clinical gestalt, disease precedence, and accuracy of laboratory/radiologic test) in calculating the chances that the patient truly has the disease in question is known as *Bayes' theorem*. This principle allows clinicians to apply the published laboratory/radiologic test characteristics (sensitivity, specificity, negative and positive predictive values) with physical examination findings and precedence of the disease in society, thereby allowing the clinician to literally calculate the probability that the patient has the disease in question, knowing the limitations of the laboratory/radiologic tests (false positives/negatives).

The test also has a strong role in the management, prognosis, and course of bacterial meningitis in regard to antibiotic deescalation. PCT may one day serve to unequivocally rule out bacterial meningitis in selected patients with an associated clinical decision instrument; however, sole reliance on the test is not currently validated (Yo et al., 2012). Combined with good clinical judgment and appropriate use of antimicrobial agents, PCT could be a valuable adjunct in the timely diagnosis and management of sepsis in patients with CNS infection and, although it has not entirely replaced the need for lumbar puncture, PCT undoubtedly has a key role in the evaluation and management of undifferentiated meningitis.

Subarachnoid Hemorrhage

- Eighty-five percent of cases originate in a ruptured cerebral aneurysm within the brain's main arterial supply at its base (circle of Willis), 10% are from a ruptured arteriovenous malformation (AVM), and 5% are from another etiology. SAH carries a high rate of morbidity and mortality and is another "can't miss" diagnosis.
- Because the etiology is most often from an aneurysmal (occasionally AVM) rupture, the presentation is abrupt and severe, with maximal pain at onset (often described as "the worst headache of one's life," although clinical presentations can vary greatly). The leaking blood may act as a chemical irritant to the meninges and, if so, may induce meningeal irritation and accompanying meningeal signs.
- One percent of the population has cerebral aneurysms.
- A well-cited 2011 cohort study by Perry et al. (2015) found all 121 of the SAHs were identified in 953 patients scanned within 6 hours of HA onset with 100% specificity and sensitivity. Although CT scanners used in this study were third generation, the research laid the groundwork for clinical evaluation of potential SAH without need for an invasive LP procedure.
- Modern high-resolution CT scans rule out SAH in nearly 100% of patients within the first 6 hours of HA.
- Acute blood appears hyperdense or bright on CT (**FIGURE 70.1**). With the passage of time, the blood catabolizes through myoglobin breakdown and becomes increasingly homogeneous or isodense. Therefore, the sensitivity of CT to detect SAH decreases as time elapses (**TABLE 70.3**).
- With a negative noncontrast head CT scan performed within 6 hours of HA onset, the risk of SAH is estimated to be 1/1,000. A 2016 systematic meta-analysis by Carpenter et al. (2016) recommends utilization of diagnostic LP only in patients who had a high pretest probability for SAH with a negative noncontrasted CT within 6 hours of HA onset. However, they did not utilize a computed tomography angiography (CTA) in their clinical pathway.

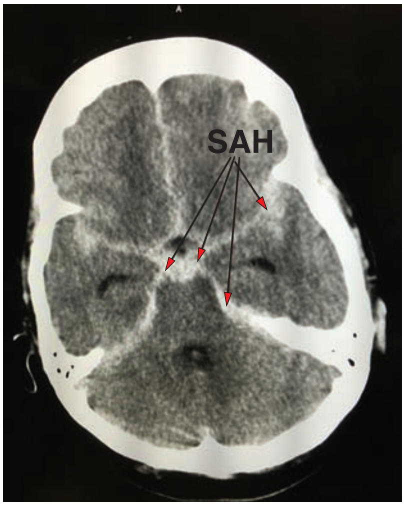


FIGURE 70.1 CT of subarachnoid hemorrhage.

SAH, subarachnoid hemorrhage

TABLE 70.3 Time Since Onset of Acute HA and Sensitivity of Plain Head CT

Time Since HA Onset	CT Sensitivity (%)
6 hours	100
24 hours	93
3 days	80
1 week	50

HA, headache.

- McCormack and Hutson (2010) have shown that the combination of a negative CT and CTA in later presentations excludes a visible SAH and vascular abnormality in 99.4% of patients (CTA detects cerebral aneurysms as small as 3 mm; **FIGURE 70.2**).
- Through extrapolated data based on the Hiroshima bomb survivors and a few retrospective pediatric cohort studies, the risk of radiation-induced cancer death from a single CT of the head is less than 1/100 in neonates and less than 1/10,000 in patients 15 years and older.
- In similar presenting cases beyond 24 hours, LP has increasingly fallen out of favor in definitively excluding SAH if CTA is available because CTA allows for a quicker diagnosis and avoids an invasive procedure, coupled with the fact that LP lacks the ability to detect:
  - Aneurysmal expansion
  - Thrombosis
  - Dissection
  - Dural venous sinus thrombosis
  - Vasospasm

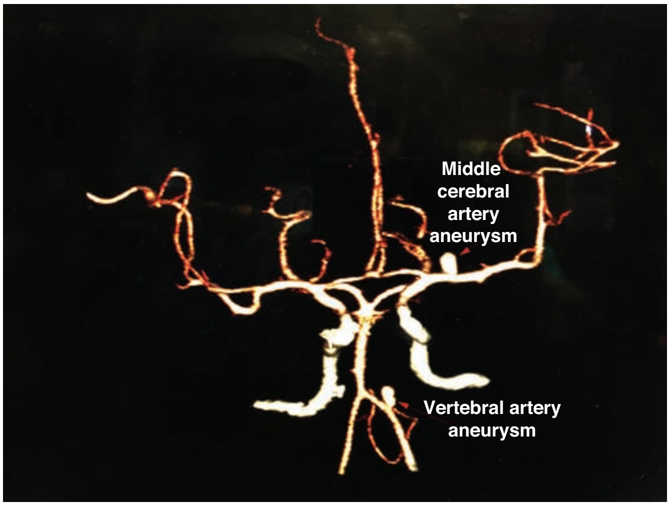


FIGURE 70.2 Brain computed tomography angiography. Notice 7-mm left vertebral artery aneurysm and 8-mm middle cerebral artery aneurysm.

Note that LP has a 15% risk of inadvertent puncture of the epidural venous plexus, introducing blood into the CSF (traumatic tap), thereby complicating the diagnosis of SAH. Due to the prevalence of traumatic taps, LP innately has a high rate of false positives.

As red blood cells (RBCs) age in the CSF, they lyse and, through myoglobin breakdown, heme molecules are released and enzymatically metabolized to produce bilirubin and xanthochromia (yellowish-colored CSF) ensues. Xanthochromia may not be present if CSF is examined within 12 hours of HA. Though this discoloration of the CSF may last for 2 weeks, interpretation via visual inspection carries a low sensitivity, whereas detection via spectrophotometry carries a low to moderate specificity (Chu, Hann, Greenslade, Williams, & Brown, 2014).

Anatomy

CEREBROSPINAL FLUID

The CSF has the following functions:

- Provides buoyancy to the brain and, by doing so, decreases its functional weight by 75%, effectively decreasing its weight from 1,400 to 50 g
- Buffers neural tissue from trauma
- Because the brain's parenchymal tissue lacks a lymphatic system, the CSF and its circulation takes on this role
- Contains antibacterial properties

CSF is made in the choroid plexuses, which are finger-like extensions with an ependymal structure that merge into the innermost ventricular lining located in the paired lateral third and fourth ventricles. These epithelial-like microvilli are composed of tight junctions on the CSF side of the ventricles and contain capillaries in their projections that are fenestrated, creating an ultrafiltration of plasma, which comprises the CSF (**FIGURE 70.3**). This in turn leads to its composition being 99% water, giving it its clear appearance.

The CSF is propelled along the neuronal axis by cranial–caudal directional pulsatile waves stemming from cerebral artery pulsations. The majority of the CSF is reabsorbed in the arachnoid granulations draining from the SAS into the dura venous sinuses and subsequently into the internal jugular veins. Twenty percent of the CSF is confined to the ventricles, 60% is in the convexities of the brain, and 20% is around the spinal cord.

After its production, the CSF circulates out of the roof of the fourth ventricle through the foramen of Luschka and foramen of Magendie to the cerebellomedullary cistern. This is a CSF reservoir secondary to a large space between the arachnoid and pia mater. From there it flows in the SAS throughout the convexities of the cerebral hemispheres and the spinal cord (**FIGURE 70.4**). The ependymal lining is freely permeable to the CSF and, in this way, is in constant chemical communication with the interstitial fluid that surrounds the neurons. Therefore, the CSF is representative of the brain's physiology and/or pathology.

A total volume of 500 mL/day of CSF is made at a rate of 20 mL/hour with an average volume at any one time of 150 mL. The 3 to 4 mL removed in a typical LP is fully replenished within 30 minutes.

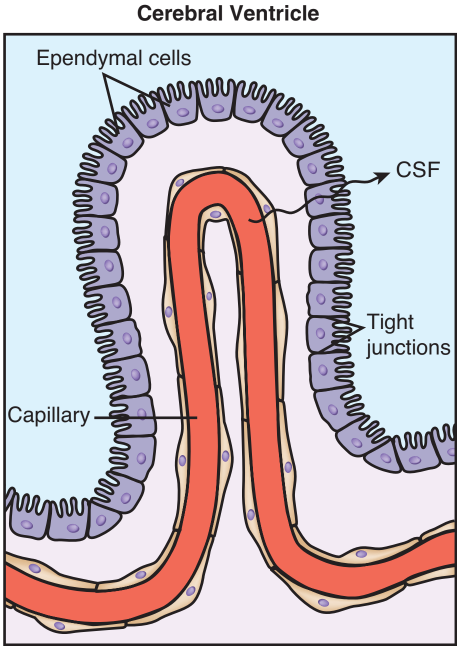


FIGURE 70.3 Illustration depicting choroid plexus lining the cerebral ventricles.

CSF, cerebrospinal fluid.

MENINGES

The brain and spinal cord are surrounded by three meninges that help protect and support the CNS: dura, arachnoid, and pia maters (**FIGURE 70.5**). The outermost dura is a fibrous, dense membrane attached to the skull and foramen magnum via the periosteum, and hence there is no true epidural space. In the spinal cord, however, the dura is not attached to the vertebral spinal canal, but rather separated by a true epidural space, which contains the vascular internal vertebral venous plexus. The arachnoid mater is anatomically deep to the dura and is a delicate membrane that closely adheres to the dura.

The potential space between the two is known as the *subdural space*. The innermost meninge, the pia mater, is an ultrafine membrane that closely adheres to the convexities of the brain and spinal cord. The space between the arachnoid and pia mater is the CSF-filled SAS.

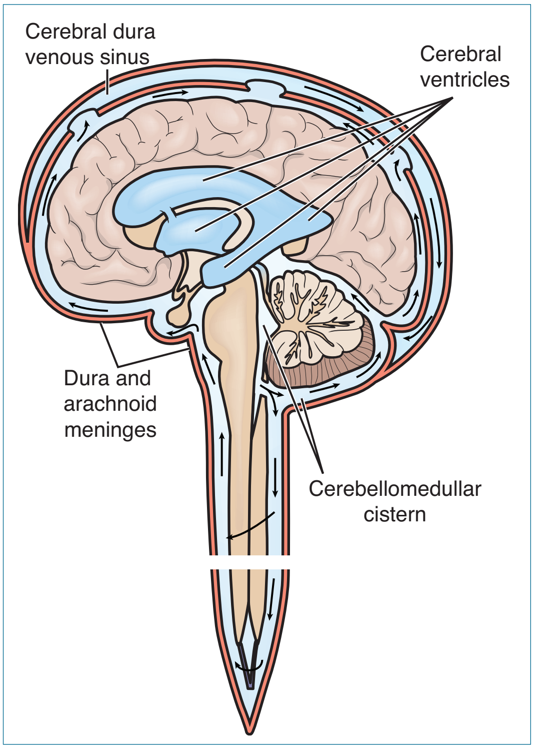

Cerebral dura venous sinus
Cerebral ventricles
Dura and arachnoid meninges
Cerebellomedullar cistern

FIGURE 70.4 Illustration depicting cerebrospinal fluid flow. Notice the CSF flows from the ventricles to the cerebral cisterns, where it then fills the entire subarachnoid space of the brain/spinal cord, and is eventually reabsorbed by the arachnoid granulations to the dura venous sinuses.

CSF, cerebrospinal fluid.

NEEDLE PASSAGE

During an LP, the needle passes sequentially through the following structures (**FIGURE 70.6**):

- Epidermis/dermis/subcutaneous tissue
- Supraspinous ligament
  - Connects the spinous processes
  - May calcify in the elderly and dictate a lateral LP approach
- Interspinous ligament
  - Connects the inferior and superior border of the spinous processes together
- Ligamentum flavum
  - Thick, elastic ligament that covers the interlaminar space between the spinal cord and the vertebral canal
- Posterior epidural space
  - Contains the internal vertebral venous plexus
- Dura
- Arachnoid
- SAS
  - Contains the cauda equina nerve roots

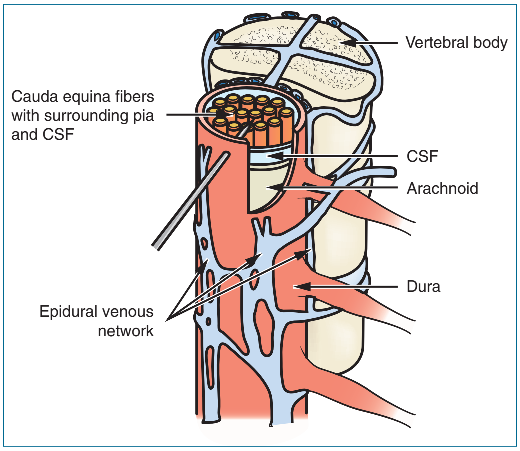

Vertebral body
Cauda equina fibers with surrounding pia and CSF
CSF
Arachnoid
Dura
Epidural venous network

FIGURE 70.5 Illustration depicting the meninges. Notice the rich venous plexus in the epidural space as a potential source of traumatic lumbar punctures.

CSF, cerebrospinal fluid.

During gestation, the spinal cord and the vertebral column are both the same length, but normal growth allows the spinal column to grow more rapidly than the spinal cord and, as such, at birth, the conus medullaris (the most inferior portion of the spinal cord) is already at the level of L3, while continued growth into adulthood causes the conus to end at L1 (68%), T12 (22%), and occasionally L2 (10%). Though the conus medullaris ends here, the posterior and anterior roots constituting the cauda equina fill the rest of the inferior lumbar and sacral portions of the spinal canal. The lumbar cistern, which is filled with CSF, is an enlargement of the SAS between the conus medullaris, the inferior end of SAS (large area of separated pia and arachnoid membranes), and the dura mater about vertebral level S2 (**FIGURE 70.7**). This area is most amenable to CSF sampling.

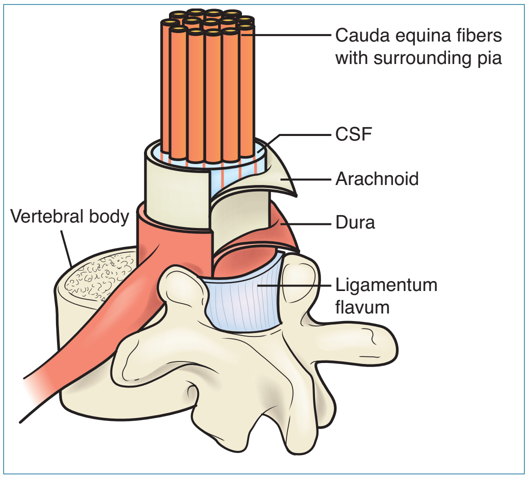

Cauda equina fibers with surrounding pia
CSF
Arachnoid
Vertebral body
Dura
Ligamentum flavum

FIGURE 70.6 Needle passage. In sequential order, the needle penetrates skin, supraspinous and interspinous ligaments, ligamentum flavum, posterior epidural space, dura, arachnoid, and finally rests in the subarachnoid space containing the cerebrospinal fluid.

CSF, cerebrospinal fluid.

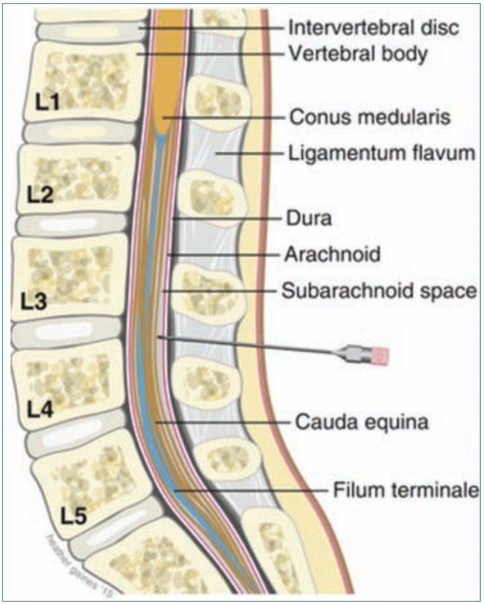

Intervertebral disc
Vertebral body
L1
Conus medularis
Ligamentum flavum
L2
Dura
Arachnoid
L3
Subarachnoid space
L4
Cauda equina
Filum terminale
L5

FIGURE 70.7 Lumbar puncture: Ideal needle entry sites are usually L4/L5 or L3/L4 interspaces.

Source: Reproduced from Shultz, C., & Asimos, A. W. (2016). Lumbar puncture and drainage. In D. A. Taylor, S. P. Sherry, & R. F. Sing (Eds.), *Interventional critical care* (pp. 225–236). Cham, Switzerland: Springer International.

PATIENT PRESENTATION

LP is used primarily as a diagnostic modality, with the majority of indications entertaining the diagnosis of meningitis. There are approximately 3,000 to 6,000 cases per year of bacterial meningitis in the adult population, with the mortality being 5% to 25%. An expedient diagnosis decreases the morbidity and mortality. Challenges hindering timely diagnosis and subsequent treatment include:

- Very young age (because of lack of nuchal rigidity)
- Elderly (comorbidities)
- Comatose state
- Immunocompromised (decreased inflammation) patient

LPs are indicated in patients presenting with signs and symptoms of meningitis. Historically, it has been used in those patients with thunderclap HA, or the worst HA of their lives, in which a CT scan of the brain evaluating SAH is normal; LP is used less often for diagnostic and therapeutic reasons in other disease states.

LP Indications

Indications	Pathology
Diagnostic	**Infection** ■ *Meningitis* ■ *Encephalitis* ■ *Myelitis* **SAH** **Inflammation** ■ *Multiple sclerosis* ■ *Guillain–Barré* **Oncology** ■ *Leukemia*
Therapeutic	■ Spinal and epidural anesthesia ■ Decompression of fluid in pseudotumor cerebri ■ Introduction of chemotherapeutic agents and antibiotics

SAH, subarachnoid hemorrhage.

CONTRAINDICATIONS AND RELATIVE CONTRAINDICATIONS

Contraindications	Etiology	Signs	Prior to LP
Elevated intracranial pressure *If missed may result in uncal herniation*	**Suspected intracranial mass lesion** ■ *Brain abscess* ■ *Posterior fossa lesion* ■ *Subdural hematoma*	■ Papilledema ■ Focal neurodeficit	**Bedside ocular ultrasound** *Most sensitive to detect papilledema* Other modalities CT head, fundoscopic exam
Spinal cord mass lesion	**Epidural abscess** **Epidural hematoma** **Epidural tumor**	■ Focal neurodeficit ■ Back pain out of proportion ■ Clinical history ⇨ *IV drug use* ⇨ *Cancer* ⇨ *Trauma*	**Imaging** ■ MRI +/- contrast ■ Myelogram **Neurosurgical consultation**
Local infection of the lumbar area	**Cellulitis/abscess** **Pressure ulcer** **Tissue compromise**	■ Clinical exam	Cervical or cisternal puncture by specialist
Bleeding diathesis	**Coagulopathy** **Anticoagulation therapy**	■ Medication history ■ Labs ⇨ *Platelets* ⇨ *PT/INR, PTT*	Correct if possible
Cardiorespiratory compromise	**Underlying disease/ comorbidities**	■ Hemodynamically unstable	Consider positioning

INR, international normalized ratio; IV, intravenous; LP, lumbar puncture ; PT, prothrombin time; PTT, partial thromboplastin time.

Elevated Intracranial Pressure and the Utility of Ultrasound

Elevated ICP is transmitted to the contiguous optic nerve sheath and may be detected via bedside ultrasound, which will show an increased optic nerve sheath diameter (ONSD). This allows a quick and simple indirect assessment of a patient's ICP, as the optic sheath is a continuum of the brain, contains meningeal covering (SAS), and its size directly correlates with an increasing ICP. Place patient in a supine position with eyes closed and apply ultrasound gel to Tegaderm or commercial barrier covering outer lid. Use the high-frequency linear probe over the eye to visualize the optic nerve and the posterior retina and freeze the image. Measure the ONSD 3 mm posterior to the globe and, if the ONSD is greater than 5 mm, an elevated ICP should be entertained (**FIGURE 70.8**).

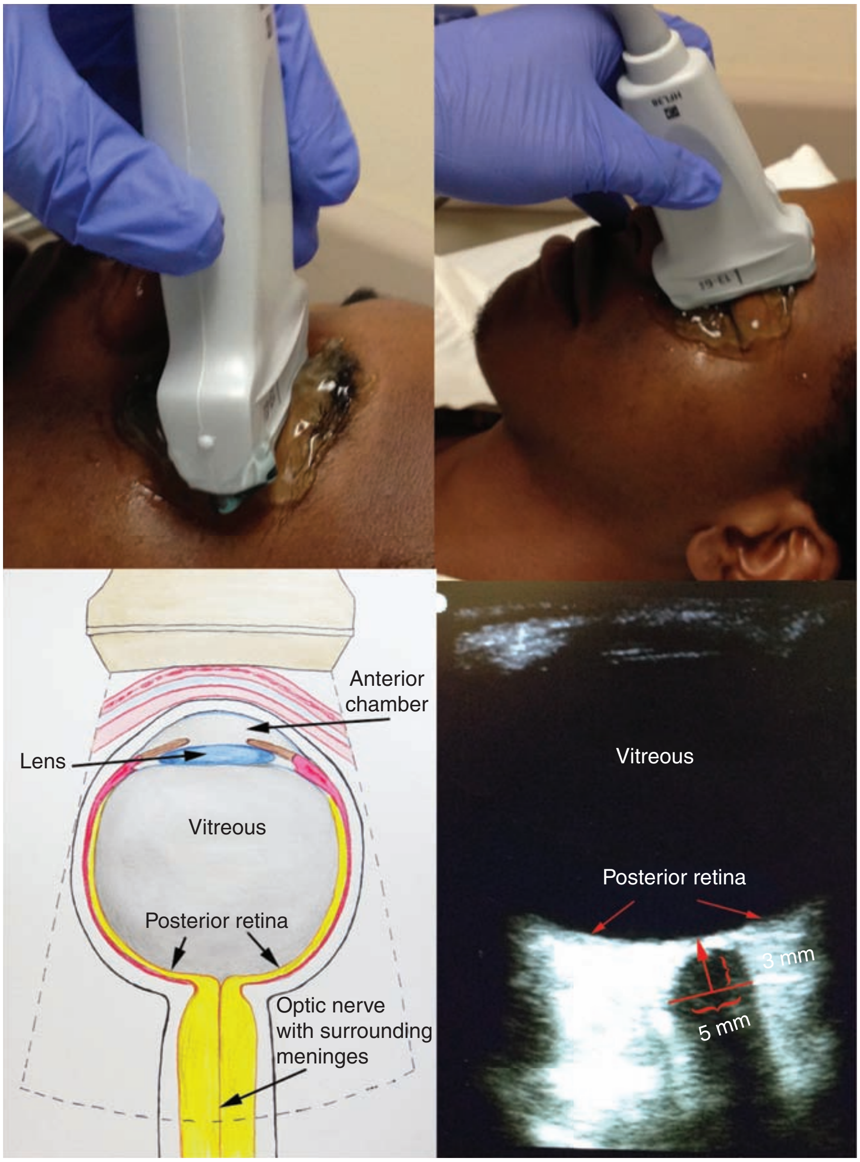

Anterior chamber
Lens
Vitreous
Posterior retina
Optic nerve with surrounding meninges
Vitreous
Posterior retina
3 mm
5 mm

FIGURE 70.8 Optic nerve sheath diameter ultrasound. Consider this modality before every lumbar puncture, as it is highly sensitive for detecting an elevated intracranial pressure.

CT Scanning Prior to LP

A brain CT should be performed before LP if an intracranial lesion with mass effect, abnormal intracranial pressure due to increased CSF pressure, or tonsillar herniation is suspected due to the risk of cerebral or cerebellar tonsillar herniation.

CT scanning should be performed prior to LP in patients with:

- Papilledema
- Elevated ONSD on ultrasound
- Focal neurodeficits
- Altered mental status
- Recent seizure
- Immunocompromise
- Known CNS mass

PROCEDURE PREPARATION

Most supplies listed are available in commercially packaged kits (**FIGURE 70.9**).

- Sterile gloves
- Skin cleanser (chlorhexidine or betadine)
- Sterile drapes
- Topical anesthetic
- Spinal needle with stylet
    - Infant: 1.5"/3.8 cm
    - Child: 2.5"/6.3 cm
    - Adult: 3.5"/8.9 cm
- Manometer
- Collection tubes

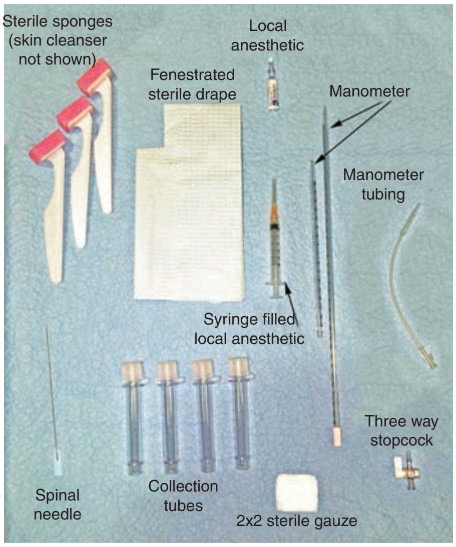

Sterile sponges (skin cleanser not shown)
Local anesthetic
Fenestrated sterile drape
Manometer
Manometer tubing
Syringe filled local anesthetic
Three way stopcock
Spinal needle
Collection tubes
2x2 sterile gauze

FIGURE 70.9 Open lumbar puncture kit.

Needle Type

Although noncutting needles (Whitacre, Sprotte, etc.) have been in use since the 1920s, their use in reducing the incidence of postdural puncture headaches (PDPHs) and the need for epidural blood patches has been recently validated in multiple studies (Xu et al., 2017). Traditional cutting needles that are still supplied in most LP trays cut the dura (the larger the needle, the larger the defect), allowing a subsequent leak, giving rise to a 30% rate of PDPH. Cutting-tip needles also carry the potential to cause nerve injury. Noncutting or pencil-tipped needles have a blunted tip and act to spread the dura fibers, thus limiting the possibility for nerve fiber damage as well as subsequent CSF leakage after the needle is removed. These atraumatic blunt-tip needles have an incidence of PDPH as low as 2%. Holst, Mollmann, Ebel, Hausman, and Wendt (1998) concluded that in an in-vivo human cadaver model CSF leak was significantly reduced with use of pencil-point noncutting needles as opposed to the traditional cutting ones (**FIGURE 70.10**). A 2018 meta-analysis by Zorrilla-Vaca, Mathur, Wu, and Grant further suggests that, regardless of the needle caliber, the incidence of PDPHs is significantly lower with use of pencil-tipped needles, unlike traditional cutting needles.

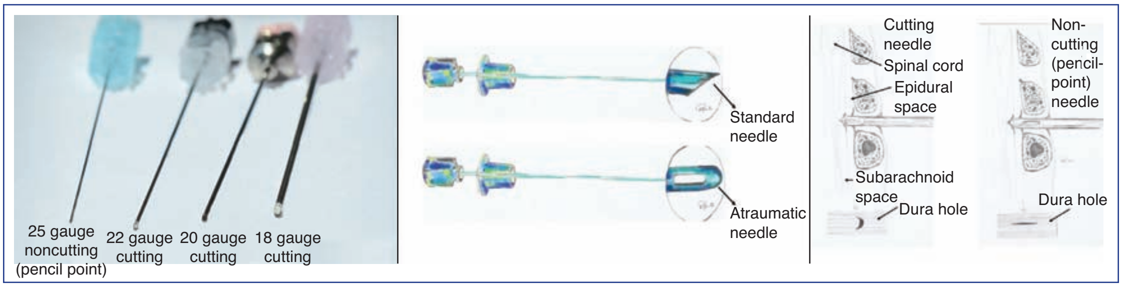

25 gauge noncutting (pencil point)
22 gauge cutting
20 gauge cutting
18 gauge cutting
Standard needle
Atraumatic needle
Cutting needle
Spinal cord
Epidural space
Subarachnoid space
Dura hole
Non-cutting (pencil-point) needle
Dura hole

FIGURE 70.10 Needle size and type comparison. Noncutting needles have a pencil-point tip that spreads the vertical dura fibers instead of cutting them, as beveled needles do. This creates less dura trauma and subsequently minimizes any postprocedure cerebrospinal fluid leak.

In a meta-analysis of 38 trials including 8,184 patients, Demaerschalk and Wingerchuk (2002) found that pencil-point noncutting needle use significantly decreased the odds of a PDPH to the point that, for every six LPs done by the pencil-point needle, one PDPH will be prevented. The distinction is so convincing that the American Academy of Neurology and the American Society of Anesthesiology have since published statements as class-one evidence for the use of noncutting needles.

Puncture of the dermis and passage through the overlying subcutaneous tissue can be more challenging with a blunt-tip needle. This has been resolved with the inclusion of an introducer in some needle devices (**FIGURE 70.11**). The introducer portion of the needle acts as a short sleeve with a cutting tip to puncture through the tough exterior tissues and set the initial trajectory for the remainder of the procedure. Although some resistance or "popping" through the dura/ligamentum flavum may be reduced with noncutting needles, there is no disparity in success rates between traditional cutting and pencil-tipped devices. A 2018 meta-analysis by Nath et al., which included 110 trials and over 30,000 patients, found no significant difference in initial success rate, number of total attempts, or failure rate with use of pencil-tipped needles.

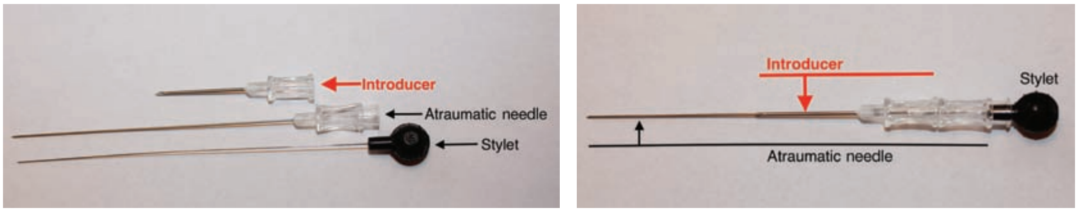


FIGURE 70.11 A traumatic pencil-tip lumbar puncture needle device with introducer. The introducer is a short cutting-needle sleeve used to puncture through the tough cutaneous and subcutaneous tissues. This provides easy entry for the atraumatic needle, which is often somewhat more difficult to use to puncture through cutaneous tissues due to the lack of cutting tip and also sets the initial trajectory for the needle and stylet.

PROCEDURE

- Place patient in either the sitting or the lateral recumbent position.

Patient Positioning

The goal of positioning the patient is to maximally flex the lumbar vertebrae and widen the interspinous distance by means of stretching the supraspinous/interspinous ligaments and ligamentum flavum. It helps to ask the patient to arch the lumbar region out, mimicking the arch of a cat. The sitting position makes this procedure somewhat easier for clinicians to perform, but if one needs a CSF pressure reading, the lateral recumbent position must be used.

SITTING POSITION

- Have the patient lean over a bedside table with their spine perpendicular to the stretcher, hugging a pillow (**FIGURE 70.12**).
- Ensure the shoulders are even.
- Studies have shown that maximal hip flexion increases the interspinous space the most. This can be accomplished by placing a stool under the patient's feet or towels under their thighs.

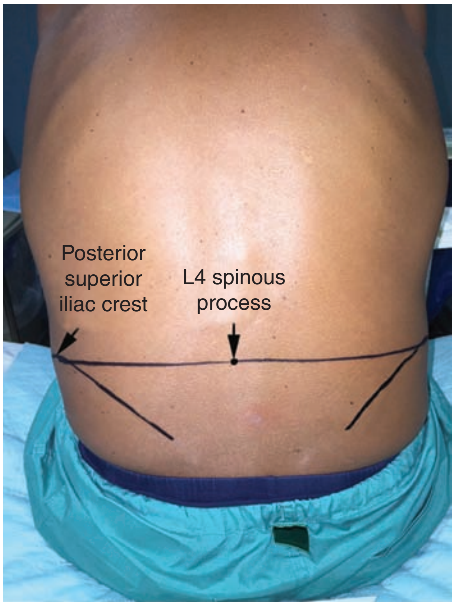


FIGURE 70.12 Sitting position. The L4 spinous process can be found by drawing a line connecting both posterior superior iliac crests and marking its midpoint.

LATERAL RECUMBENT POSITION

- Have the patient lie on their left lateral side with the lumbar spine parallel to the stretcher and the hips and shoulders flexed so they're perpendicular to the stretcher.

- An assistant facing the patient can encourage an optimal position by placing one arm behind the patient's flexed knees and the other behind the shoulders to ensure the shoulders are equally perpendicular to the stretcher (**FIGURE 70.13**).
  - Avoid flexing the neck because this does not widen the lumbar interspinous space and may impede breathing.
- Using sterile gloves, apply the skin cleanser using a concentric motion from the needlepoint entry site outward.
- Place the fenestrated sterile drape on the patient.
- Inject the local anesthetic over the needle-site entry point subdermally.
  - One can apply local anesthetic in a long-track manner using a long 27-gauge 1.5" needle and anesthetize the interspinous ligament up to the point of the ligamentum flavum in the same direction of the LP needle placement (**VIDEO 70.1**).
  - In pediatric patients, randomized trials have shown that both infiltrative and topical anesthesia can reduce pain associated with performing an LP, even in a neonatal patient.

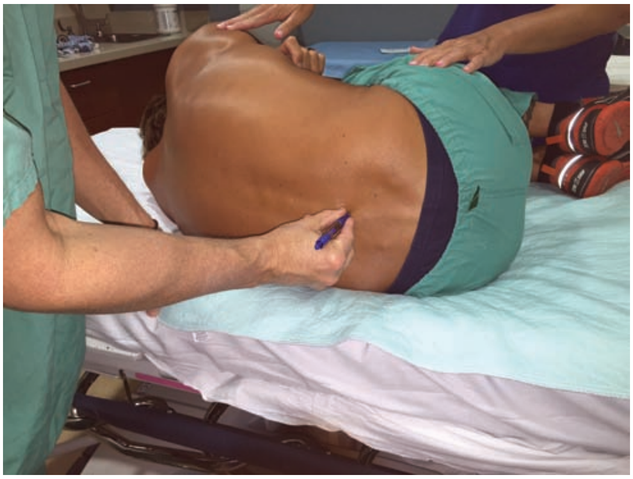
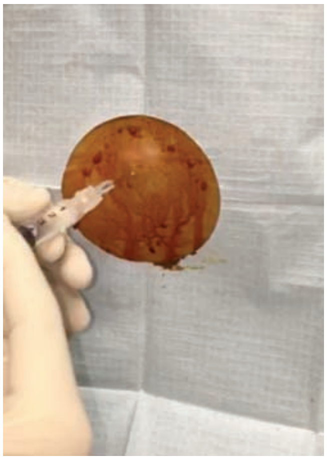


FIGURE 70.13 Lateral recumbent position.



VIDEO 70.1 Long-track local anesthesia.

Needle Positioning

Palpate the posterior superior iliac crests and note the midpoint as it intersects the L4 spinous process. Mark this area by using a skin marker or pressure divot (**FIGURE 70.14**). Ultrasound-guided landmark identification (USGLMI) should be used if the tactile appreciation of pertinent anatomy is challenging in either the lateral decubitus or the sitting position (**FIGURE 70.15**).

- Using the transverse view with the high-frequency linear probe, find the center of the L3 or L4 spinous process (hyperechoic crescent shape with acoustic shadowing) and mark a point above and below in the midprobe area.
- Place the probe in the sagittal plane and place over adjacent spinous processes in the already identified midline (already marked by the two vertical points) and mark a point in between two adjacent spinous processes on either side of the midprobe area.
- Connect the horizontal and vertical points.
- This dot represents the exact midline coordinate and the interspinous space between the two adjacent spinous processes and the needle insertion point.
- The curvilinear probe may be required for the obese patient (lower frequency/greater depth) and for identification of the ligamentum flavum/dura, SAS, and needle depth.

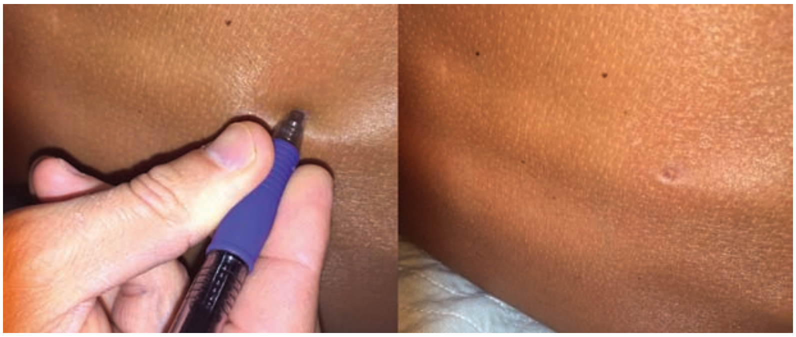


FIGURE 70.14 Skin divot. Because the skin cleansing occasionally removes marker ink, depression of the skin may serve as better guidance on commencement of needle placement.

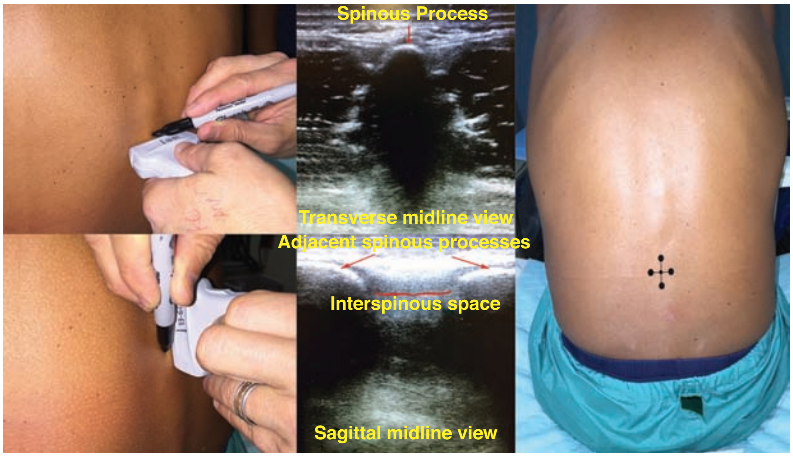
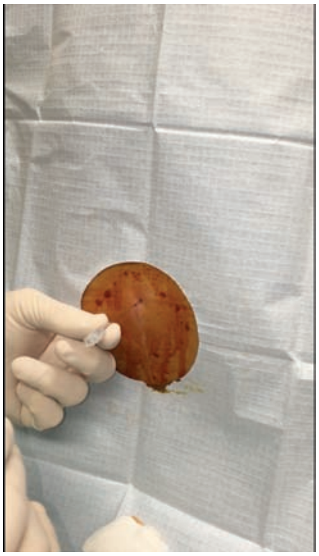


FIGURE 70.15 Ultrasound-guided landmark identification.

Because the spinal cord usually ends at the level of L1 in adults, insert the needle at the L3/L4 or the L4/L5 interspace; in younger pediatric patients, the spinal cord ends at L3, so the L4/L5 level is recommended.

- Needle without introducer: Insert the needle with a stylet at the superior aspect of the inferior spinous process and angulate 15-degree cephalad toward the umbilicus (**VIDEO 70.2**).
- Needle with introducer: When using an atraumatic pencil-tipped needle with introducer, first take the introducer off the needle assembly and insert the introducer into the subcutaneous tissue. This will ultimately guide the trajectory of the needle so take great care to position the introducer in the correct plane, angle, and position as described previously. Then insert the needle with stylet into the introducer (**FIGURE 70.16**).
- In the classic way of holding the needle, both thumbs are placed on either side of the proximal needle hub while both index fingers are used to support the distal needle close to the skin to advance the needle forward.
- Another technique puts the hub between the dominant thumb and index finger and the nondominant thumb and index finger support the distal needle close to the skin to advance it forward (**FIGURE 70.17**).
    - In pediatric patients, the needle should be inserted with less of an angle and possibly with no angle as their spinous processes are flatter.
    - If using a cutting needle, ensure the bevel is in the sagittal plane in order to lessen cutting of the vertical dura fibers.



VIDEO 70.2 Lumbar puncture.

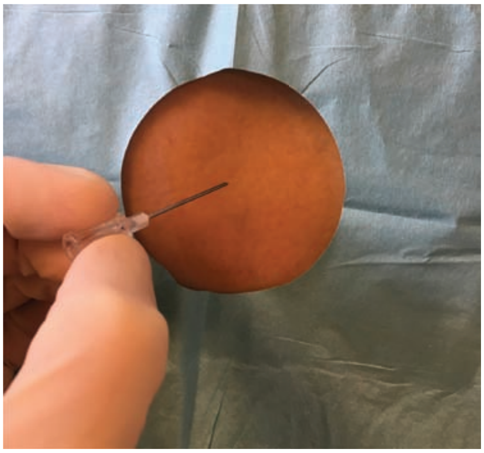


FIGURE 70.16 Atraumatic pencil-tipped needle with introducer. First, take the introducer off the needle assembly and insert the introducer into the subcutaneous tissue to set the trajectory for the spinal needle. Then insert the needle with stylet into and through the introducer.

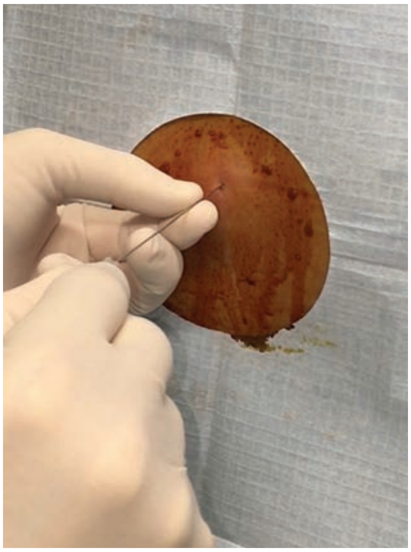


FIGURE 70.17 Holding the needle (note there is no introducer).

NOTE *Because of the decrease in tactile sensation that occurs when the needle pierces the dura/ligamentum flavum ligaments, use of the "Cincinnati" method is suggested. This includes continuing to advance the needle and stylet past the dermis. The stylet is then removed (avoids dislodging a plug of skin that could be transported into the SAS), and the needle is slowly advanced until CSF is seen flowing. In this technique, one avoids inserting the needle too far into the anterior epidural space and its venous plexus contents. Studies have shown this method decreases traumatic LPs in pediatric patients.*

- As the needle passes through the ligamentum flavum and/or dura, one may appreciate a decrease in resistance and a "popping" sensation; however, this may not be prominent with atraumatic needles.
  - In the very young pediatric patient, this popping sensation may be absent.
- At this point, stop, withdraw the stylet, and, if no fluid returns, reinsert the stylet and repeat at 2-mm increments.
  - If fluid is not acquired and/or bone is encountered, withdraw the needle to the level of the subcutaneous tissue without exiting the skin and redirect the needle (typically more cephalad).
  - If CSF flow is poor, a cauda equina nerve route may be obstructing the needle, and one should rotate the needle 90 degrees.

If one encounters blood and it clears, the needle is in the SAS, and tube collection can follow after a few drops are discarded and sequential cell counts are obtained on tube 1 and tube 3 or 4.

If the blood does not clear, the needle has most likely been advanced into the venous plexus within the ventral epidural space and must be removed completely.

- If obtaining an opening pressure, the patient must be in a lateral recumbent position.
- Attach a stopcock to a flexible connector or to the spinal needle itself while pointing the lever away from the patient.
- Record the CSF column level at the highest point of respiratory and cardiac variations (an abnormal reading is anything above 25 cm of water).
- Now, turn the lever of the stopcock toward the patient so fluid in the manometer may be collected.
- Collect fluid by allowing it to drip into the collection tubes.
- **Never aspirate the CSF, as even a small amount of negative pressure can precipitate a hemorrhage.**
- The amount of CSF collected should be limited to the smallest amount needed for testing, typically 3 to 4 mL with approximately 1 mL placed in each tube.
- After adequate CSF fluid collection, replace the stylet and remove the needle.
- In older patients, the supraspinous and possibly the interspinous ligaments may calcify, requiring a lateral approach.
  - In this technique, the needle entry point is lateral to the calcified ligaments mentioned and it is vectored toward the midline to bypass all extramedullary ligaments, piercing the ligamentum flavum after passing through various paraspinal muscles (**FIGURE 70.18**).
  - Place the needle just above the transverse process of L4 or L5 and direct it medially and cephalad.

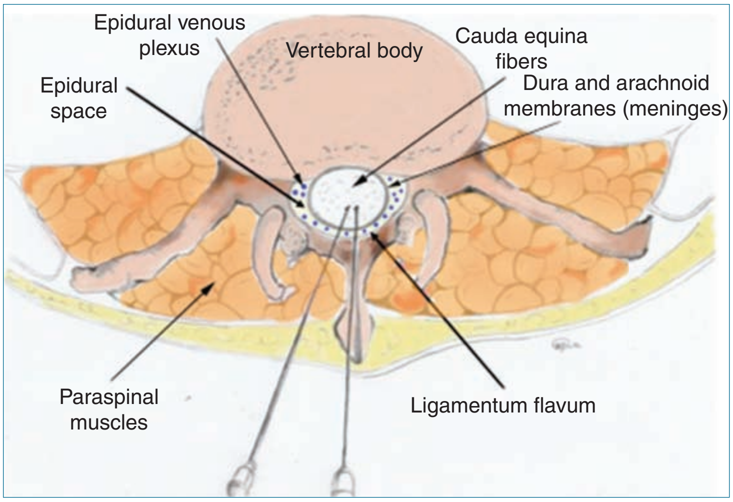


FIGURE 70.18 Medial and lateral approach. In cases in which the supraspinous/interspinous ligaments are calcified, one may enter lateral to the spinous process (all the while vectoring toward the midline) while bypassing these ligaments and piercing the ligamentum flavum via the paraspinous muscles.

ULTRASOUND GUIDANCE

Landmark Identification

Though this modality for landmark identification has been described since the 1970s, its use has not been embraced until recently. With ultrasound machines becoming more ubiquitous in clinical arenas, and familiarity gained by such common procedures as central venous catheter (CVC) placement and diagnostic abdominal sonography (focused assessment with sonography in trauma [FAST], abdominal aortic aneurysm [AAA]), its use in other areas, including its static use in identifying the midline spinous processes in anatomically challenging patients, is warranted and supported by the literature.

Landmarks that are normally palpated by the clinician may not be appreciated or may be altered in some patients:

- Obesity USGLMI is successful in the majority of patients with a body mass index [BMI] greater than 30)
- Osteoarthritis
- Ankylosing spondylitis
- Kyphoscoliosis
- Previous lumbar surgery altering landmarks
  - In cases involving lumbar fusions, if a laminectomy was done at the same time, one may pass the needle in this area void of bone.
  - A lumbar x-ray or CT may identify lateral fusions, in which case a medial approach still may be obtainable.
  - May need to perform the procedure at a level above or below the previous surgery.
- In patients with spinal stenosis, one may need to use the L2/L3 interspace.

The use of bedside ultrasound in a static manner may act as the “hands” of the clinician in identifying landmarks used for needle insertion. The inability to identify landmarks may lead to the clinician’s reluctance to perform the procedure, higher rates of complication, and increasing patient discomfort. Furthermore, USGLMI prevents treatment without a CSF sample and may avoid fluoroscopy (transport, radiation, availability).

A 2019 meta-analysis by Gottlieb, Holladay, Peksa, and Carpenter concluded that USGLMI has been linked to increased success rates, decreased traumatic and failed attempts, shorter time to successful insertion, and reduced patient pain scores. Ferre and Sweeney (2007) found that nonradiology clinicians can identify five structures (spinous processes, ligamentum flavum, dura, epidural space, and SAS) in patients with an average BMI of 31 with 88% doing so in less than 1 minute and 100% in less than 5 minutes. Stiffler, Sharhabeel, Wilber, and Robinson (2007) have shown that as a patient’s BMI increases, so does the difficulty in palpating landmarks and the needle depth (**TABLE 70.4**). When more than one attempt is required, a meta-analysis has shown that there is an inherent 15% traumatic LP rate that is higher as BMI increases. This may add confusion to the diagnosis and possibly the administration of unnecessary antibiotics.

TABLE 70.4 Needle Depth Based on BMI

BMI	Difficulty Palpating Landmarks (%)	Needle Depth (cm)
<25	5	4.4
>25–30	33	5.1
>30	68	6.4

BMI, body mass index.

Transverse View

- Exact position of a spinous process

Sagittal View

- Interspinous process area
- Depth to the SAS
- Needle angle

POSTPROCEDURE CONSIDERATIONS

CSF Analysis in Bacterial Meningitis

- CSF culture is required. (CSF exam and clinical picture is only 70% sensitive.)
- Regardless of the causative organism of bacterial meningitis, CSF findings in acute bacterial meningitis are often similar.
- Expedient transport to the laboratory is mandatory as cells begin to lyse within an hour, and this process is slowed by refrigeration (especially meningococcal organisms).
- The white blood cell (WBC) count of CSF is almost always between 1,000 and 10,000 and rarely is less than 100 in cases of bacterial meningitis.
    - In 90% to 95% of patients, polymorphonuclear (PMN) cells account for the total WBC count of the CSF, and in less than one quarter of cases do PMN cells comprise less than 80% of the total leukocyte count.
- Gram stain is only 80% sensitive.
    - *Streptococcus/Staphylococcus*—Gram-positive cocci
    - *Neisseria*—Gram-negative intra/extracellular diplococci
    - *Haemophilus*—Gram-negative bacilli
- The polymerase chain reaction (PCR) has a sensitivity over 90% and 100% specificity for *S. pneumoniae*, *Neisseria meningitidis*, and *H. influenza.*
    - In some centers, *N. meningitidis* is being solely diagnosed via PCR without cultures.
    - PCR also detects HSV and enteroviruses.
- The opening pressure is typically increased in almost all patients, with 90% of cases having an opening pressure of over 200 mmHg.
    - Pressure will increase parallel with the progression of the disease, and it returns to normal with recovery.
- The CSF glucose is usually moderately to severely reduced; in 75% of patients, it is less than 50 mg/dL, and in 25% of cases, it is less than 10 mg/dL.
    - The normal range for CSF/serum glucose ratio is greater than 0.6 (two-thirds the serum glucose).
    - Usually normal in viral meningitis, but may be slightly low.
    - CSF glucose has a higher sensitivity than protein.
- The CSF protein concentration is almost always increased, and in more than 80% of patients, the absolute value is more than 80 mg (usually greater than 500 mg).
    - Viral infections with lymphocytic pleocytosis have a lesser (sometimes normal) elevation of protein, usually between 50 and 100 mg/dL.
- Other studies that may be obtained depending on the clinical scenario:
    - India ink—Cryptococcal surface antigen
    - Viral specific immunoglobulin (IgG)/immunoglobulin M (IGM) for mosquito-borne viral encephalitis
    - Acid-fast smear—Bacilli (culture for *Mycobacterium tuberculosis* to be done in countries with high incidence of tuberculosis [TB])
    - Most commonly seen in the United States in cancer and/or immune-compromised patients
    - Induces very high CSF protein levels
- *Borrelia burgdorferi* antibodies—Lyme disease
- HSV analysis

EDUCATIONAL POINTS

- Although clinical dogma states lying flat for 2 to 3 hours postprocedure decreases CSF leakage and risk of postprocedural HA, there is no evidence to support this. To avoid post-LP HA, use an atraumatic pencil-tip needle.
- Never aspirate CSF as even a small amount of negative pressure can precipitate a subdural/epidural hemorrhage.
- CT of the brain does not rule out meningitis, nor does any imaging modality; only an LP does.
- PCT is an ***adjunct tool used only*** to help rapidly and accurately distinguish viral from bacterial meningitis. ***No test can ever replace the clinical encounter***. The test also has a strong role in the management, prognosis, and course of bacterial meningitis in regard to antibiotic de-escalation.
- If the blood clots, suspect a traumatic tap (SAH blood has already been defibrinated and therefore will not clot).
- When obtaining an opening CSF pressure, the patient must be in the lateral decubitus position, as changes in CSF pressure are seen in varying body positions.
    - This is due to changes in venous pressure that are related to cerebral perfusion pressure and, therefore, CSF pressure.

- Although the detection of bacterial antigens, the Gram stain (less commonly done anymore), and/or an affirmative culture ensure the diagnosis, the following have a high correlation with the diagnosis of a bacterial etiology:
  - CSF glucose/blood glucose less than 0.4
  - CSF WBC greater than 500/uL
  - CSF lactate greater than 30 mg/dL (not routinely tested)
- Although recent antibiotics may decrease the sensitivity of the Gram stain and culture, they have no adverse effect on the WBC, glucose, or protein measurement.
- Nuchal musculature is poorly developed until 8 weeks of age, and therefore fever in infants usually warrants an LP.
- If a noncutting needle is not available, use the smallest needle gauge possible and ensure the bevel is oriented in the sagittal plane of the spinal column in order to spread vertical dura fibers.
- One-third of ED patients will experience difficulty with LPs without USGLMI.
- One percent of all HA presentations to the ED are an SAH and 1% of the population has cerebral aneurysms.
- Five percent of SAHs are missed on initial ED presentation (Vermeulen & Schull, 2007). Have a high suspicion of HAs that are abrupt in onset or "worst of life."
- Before a major hemorrhage, 40% of patients with aneurysmal SAH have had a "sentinel thunderclap" or "warning leak" HA, which is not a full rupture of the aneurysm but rather a temporary leak; this temporary leak may precede a full rupture anywhere from hours to months and the astute clinician must recognize such a clinical presentation (acute/severe HA with a negative CT) and capitalize upon a CTA for a definitive diagnosis.
- Blood released into the SAS will diffuse away from the source of bleeding and hemolyzes within hours, rendering computed tomography less able to distinguish the blood from CSF as time passes.
- Besides significantly decreasing the incidence of PDPH, Engedal, Ording, and Vilholm (2015) have shown in 501 patients that switching from a 22-gauge cutting to a 25-gauge noncutting needle decreased hospitalization rates from 17 to 2, missed workdays from 175 to 55, and the number of blood patches needed went from 10 to two. Although the atraumatic needles were more expensive than standard cutting devices, they effectively decreased cost by reducing PDPH treatment modalities by 76%.
- An epidural blood patch is effective in the treatment of PDPH in at least 85% of patients treated, usually within 30 minutes.
- One small clinical trial in postpartum women who had received spinal anesthesia found that infusing 500 mg of caffeine had an absolute risk reduction of 61% in patients with PDPH, although a 30% recurrence rate was reported. However, its efficacy in emergency settings is unknown.

COMPLICATIONS

Most complications can be avoided by careful assessment and physical exam prior to the procedure, including a thorough neurological exam and fundoscopic or ocular ultrasound for detection of papilledema (**TABLE 70.5**).

TABLE 70.5 Complications of Lumbar Puncture: Etiology, Signs, and Avoidance

Complication	Etiology/Signs	Avoidance
Cerebellar herniation	Elevated ICP due to brain-space-occupying mass causing pressure gradient. LP may precipitate uncal herniation. **Pseudotumor cerebri, elevated ICP is uniform throughout, LP is not only safe but also therapeutic.*	**Bedside ocular ultrasound** ■ *Most sensitive in detecting papilledema* ■ Other modalities ■ CT head, fundoscopic exam
Epidural/subdural hematoma	■ Bleeding diathesis ■ Thrombocytopenia ■ ITP ■ Leukemia	**Identify and correct** if possible ■ Medication history ■ Labs ⇨ *Platelets* ⇨ *PT/INR, PTT*

(*continued*)

TABLE 70.5 Complications of Lumbar Puncture: Etiology, Signs, and Avoidance (*continued*)

Complication	Etiology/Signs	Avoidance
PDPH	Occipital/cervical HA within 5 days after LP: persistent CSF leak can lead to intracranial hypotension (buoyancy of the brain as it sits in the cranial vault is decreased) and subsequent traction on the pain-sensitive dura at the base of the brain. **Symptoms** ■ Neck stiffness ■ Tinnitus ■ Vertigo ■ Hypoacusia *(decreased endolymph volume)* ■ Photophobia ■ Diplopia/blurry vision *(stretching of CN VI)* ■ Aggravated within 15 minutes of standing ■ Improves within 15 minutes after laying flat **Risk Factors** ■ Cutting needles with larger sizes ■ Young age ■ Female gender ■ History of chronic HAs ■ Lower BMI	**Atraumatic pencil-tipped needles** *(when unavailable, smaller size of cutting needle)* **PDPH occurs in 80% of patients on whom 16-gauge needle was used.*
Infection	■ Meningitis ■ Discitis ■ Osteomyelitis	**Sterile technique**
Subarachnoid epidermal cyst formation	Occurs when a skin plug is introduced and embedded in the SAS upon needle placement.	**Standard use of stylet**
Paresthesia	Needle irritation of the cauda equina nerve route	**Immediate repositioning of needle**

BMI, body mass index; CN, cranial nerve; CSF, cerebrospinal fluid; HA, headache; ICP, intracranial pressure; INR, international normalized ratio; ITP, immune thrombocytopenic purpura; LP, lumbar puncture; PDPH, postdural puncture headache; PT, prothrombin time; PTT, partial thromboplastin time; SAS, subarachnoid space.

PEARLS

- The most feared complication of an LP is cerebral herniation; therefore, it is paramount that a detailed thorough neurological and fundoscopic exam precedes the procedure.
- *N. meningitidis* presentations do not induce a petechial nonblanching rash in 40% of initial presentations; maintain a high clinical suspicion.
- Classic triad of fever, altered sensorium, and neck stiffness occurred only in a minority of patients, 44% overall.
- Patients will usually not have an adverse outcome if an LP is omitted, but may indeed have an adverse outcome if definitive treatment, such as antibiotics, are delayed.
- Ultrasound-guided landmarks double the success rate in the obese patient.
- Meticulous patient positioning is critical to procedure success.
- Accurate landmark identification can occur via the use of a pen-induced skin indentation.
- Collect no more CSF fluid than needed for testing (3–4 mL).
- Always remove the needle with a stylet in place.
- Bed rest, number of needle attempts (assuming unsuccessful dura penetration), in vitro fertilization (IVF), supine position, and clinical experience of the clinician have not shown in any studies to decrease the rate of PDPH.
- Only smaller needle size and noncutting type have shown to decrease the rate of PDPH.
- Flow rate does not change with needle type or size.
- Apply sterile drapes to the patient while the skin cleanser is still wet in order to facilitate added drape adherence.

- Ensure collection tubes are placed in sequential order at procedure setup.
- Reidentify landmarks just before insertion of the needle, as subtle movements may change the overlying skin and spinous process relationship.
- If the CSF flow is poor, a cauda equina nerve route may be obstructing the needle, and one should rotate it 90 degrees.
- Dehydrated patients may require the sitting method to collect CSF.
- Bacterial meningitis usually causes some alterations of the sensorium, whereas a viral etiology does not (inflammation limited to the meninges) except HSV.
- In a traumatic tap, using an RBC threshold of 100 can rule out an SAH, whereas RBCs greater than 10,000 increase the likelihood of an SAH by a factor of 6.
- The best treatment for bacterial meningitis is prevention via vaccination against the common pathogens.
- CSF glucose less than 50% of the serum glucose should raise the suspicion of bacterial meningitis.
- Blood culture has a 50% to 80% sensitivity in bacterial meningitis.
- Crul, Gerritse, van Dongen, and Schoonderwaldt (1999) describe a patient with a persistent PDPH refractory to three epidural blood patches who was treated with 3 mL of fibrin glue with success.
- Although bacterial meningitis is a medical emergency and viral meningitis is not, be suspicious of an HSV etiology in those patients with signs of viral meningitis coupled with an altered sensorium, as this virus induces inflammation of the brain and subsequent encephalitis.
- One percent of the population has cerebral aneurysms; have a high suspicion on those patients presenting with an acute onset of an HA.

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CHAPTER 71

Clearing the Cervical Spine

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BACKGROUND

Approximately 17,000 spinal injuries occur annually in the United States. The majority of cervical spinal injuries (CSI) occur in persons aged 16 to 30, most of whom are male (80%). Males also represent nearly all (90%) sports-related CSIs (American Association of Neurological Surgeons, n.d.). The most common causes of spinal cord injuries are motor vehicle accidents followed by falls, violence (including penetrating gunshot wounds), and sports. Note 5-10% of unconscious patients who present to the ED secondary to a MVA or fall have a significant injury to the cervical spine. Also, the incidence of sports related cervical spine injuries has decreased over the years, accountable to the illegal action of spearing in football since 1976, improved protective equipment and better coaching in terms of technique. https://emedicine.medscape.com/article/824380-overview. More than 50% of spinal cord injuries involve the cervical spine (c-spine) and lead to complete or incomplete tetraplegia, also known as *quadriplegia* (National Spinal Cord Injury Statistical Center, n.d.). The majority of cervical spine fractures occur predominantly at 2 distinct levels: one third of injuries occur at the level of C2, and one half of injuries occur at the level of C6 or C7. Most fatal cervical spine injuries occur in upper cervical levels, either at craniocervical junction C1 or C2.

It is imperative that clinicians are competent in evaluating and clearing the c-spine. A thorough history, including mechanism of injury and use of alcohol and illicit substances that can impair the individual's expression and response, should be obtained. Focused examination of the entire spinal column, as well as a head-to-toe clinical assessment for other injuries that may be considered distracting, should be performed. As their name implies, distracting injuries occur elsewhere and distract the patient's perception of pain in the c-spine. Examples of distracting injuries may include, but are not limited to, thoracic injuries; skull fracture; intracranial hemorrhage; facial bone fractures; bone fractures of the extremity, torso, pelvis, or thoracic or lumbar spine; and intra-abdominal injury. In situations in which a patient exhibits no spinal pain but has a distracting injury and a high-risk mechanism of injury (i.e., motor vehicle collision/rollover/ejection, pedestrian or bicycle collision, axial load injury, etc.), CSI must be suspected. Holly et al in the journal of neurosurgery have shown that 5.4% of moderate to severe head injury patients harbor a significant cervical spine injury. https://thejns.org/spine/view/journals/j-neurosurg-spine/96/3/article-p285.xml. Decision-making, including selection of the most appropriate medical imaging (plain radiograph and CT scan) to assist in c-spine clearance, is supported with the use of evidence-based screening tools such as the National Emergency X-radiography Utilization Study (NEXUS) and Canadian C-Spine Rule (CCR).

Cervical X-radiography has historically been the first-line study for rapid evaluation and clearing of the c-spine. However, with new data demonstrating that significant injuries are missed on radiographs (20% of fractures), CT scan of the c-spine is excellent in detecting fractures and osseus compromise of the canal. As an example, many odontoid fractures are in the axial plane and CT allows coronal and sagittal reformatting for better depiction. CT, however, is not meant to identify a ligamentous, disk and spinal cord injuries; these types of injuries are evaluated by an MRI.

Once medical imaging is obtained for c-spine clearance, competent review of the images must be performed. ***The intention of this chapter is to discuss clearing a c-spine, both clinically and via medical imaging. It is not meant to be a full discussion of medical imaging interpretation. All failsafe measures must be in place to ensure competent and accurate interpretation of medical imaging.***

PATIENT PRESENTATION

- Pain in the c-spine
  - Posterior neck
  - Spinous process
- Focal neurological symptoms, such as weakness, numbness, and/or tingling in any extremity
- Paralysis
- Patient arrives with cervical collar in place

TREATMENT

The goals of treatment are to determine whether a CSI exists, and to prevent further injury while doing so. This is accomplished through history taking and physical examination, screening tools, and/or medical imaging in the patient who has undergone a suspected or actual traumatic experience. ***If a CSI is suspected and the patient does not have a properly sized and placed cervical collar, one must be applied until a full history, physical examination, and screening can be completed.***

- Thorough history
  - Age
  - Timing
  - Mechanism of injury
  - Substance use (alcohol, marijuana, illicit drugs, etc.)
  - Occupation
  - Ambulatory at scene
  - Paresthesia, paralysis, numbness, tingling
  - Incontinence of stool or urine
- Physical examination
  - Primary survey
  - Spine examination
    - Tenderness with palpation (anterior, lateral, posterior)
    - Inability to assess range of motion due to collar, pain, or suspected injury

SPECIAL CONSIDERATIONS

The ability to clear a patient's c-spine clinically is altered and/or cannot be accomplished in the following populations:

- Pediatric patient (<1 year of age)
- Geriatric patient (≥65 years of age)
- Pregnant patient
- Patient impaired from alcohol, marijuana, and/or other illicit substances
- Decreased level of consciousness
- High-risk factor for injury

PROCEDURE PREPARATION

Deciding on the best way to clear the c-spine (without medical imaging, termed *clinical clearance,* vs. the use of imaging, *radiographic clearance*) is guided by evidence-based screening tools. The following two screening tools are essential components of c-spine clearance.

NEXUS Criteria

- Multiple studies demonstrate sensitivity of 83% to 100% for CSI (with the majority finding 90%–100% sensitivity) when using NEXUS.
- Can be utilized on all ages. However, the sensitivity decreases to 66% to 84% in persons over the age of 65 years. It is also not recommended on pediatric patients under the age of 1 year.
- Potential to decrease imaging by 12.6%.
- NEJM article has shown for alert patients with trauma who are in stable condition, the Canadian C-Spine Rule is superior to the Nexus Criteria with respect to sensitivity (99.4% vs 90.7%) and specificity (45.1% vs 36.8%) for cervical-spine injury, and its use would result in reduced rates of radiography (Stiell et al., 2003).

- The presence of any of the following five factors necessitates radiographic imaging.
    - Focal neurologic deficit present
    - Midline spinal tenderness present
    - Altered level of consciousness
    - Intoxication
    - Distracting injury

Canadian C-Spine Rule

- High sensitivity rate of 99% to 100% for ruling out CSI in alert, stable trauma patients.
- When used, can reduce the use of imaging for clearance of the c-spine.
- Can be used in the intoxicated patient as long as they are alert and cooperative.
- Has been criticized for the difficulty in memorizing its requirements due to multiple factors needed.
- Must assess three sets of considerations: exclusion criteria, high-risk factors, and low-risk factors.
- Exclusion criteria: The presence of any one of these indicates that the CCR cannot be used in this patient.
    - Nontrauma patient
    - Glasgow coma score <15
    - Age <16 years of age
    - Unstable vital signs
    - Acute paralysis
    - Known vertebral disease
    - Previous c-spine surgery
- Is there a high-risk factor? If any of these factors are present, the c-spine cannot be cleared clinically and imaging is required.
    - Age ≥65 years
    - Mechanism of injury considered to be dangerous
    - Numbness or tingling present in extremities
- Are there low-risk factors present?
    - Simple rear-end motor vehicle crash
    - Sitting position in the ED
    - Ambulatory at scene
    - No midline tenderness to the spine
- If there are no exclusion criteria and no high-risk factors, and the low-risk factors are present, assess whether the patient is able to actively rotate the neck 45 degrees in each direction.

PROCEDURE

Clinical Clearance

- Clinical clearance can be performed if there are no exclusion criteria and no high-risk factors, the low-risk factors are present, and the patient is able to actively rotate the neck 45 degrees in each direction.
- If the criteria for NEXUS or CCR are not met, then medical imaging must be performed. Do not proceed with clinical clearance.
- Before any neck rotation test is performed, at least one of the following low-risk factors must be present:
    - Simple rear-end motor vehicle collision
    - Patient ambulatory at any time since injury
    - Delayed onset of neck pain
    - Patient in sitting position in the ED
    - Absence of midline c-spine tenderness
- Assess cervical range of motion, beginning with lateral rotation.
    - If the patient can rotate the neck 45 degrees in each direction without pain, have them flex and extend the neck.
    - Full range of motion (either active or passive) without pain should be demonstrated.
- If the patient has no pain with full range of motion in the c-spine, the c-collar may be removed.

Radiographic Imaging for Clearance

When the c-spine cannot be cleared clinically, radiographic imaging is needed. Independent evaluation of medical images should only be completed by a trained clinician, and, as a safety measure, images should always be evaluated by an additional radiologist.

- According to *Advanced Trauma Life Support Student Course Manual* (Committee on Trauma, 2018), the primary screening modality for possible CSI is CT if available. If CT is not available, anteroposterior (AP), lateral, and odontoid plain films are necessary for accurate assessment of the c-spine.
  - Assess adequacy of all X-rays.
  - Use a systematic approach if using X-rays (CT not available)
    - View the cervical spine as 3 distinct columns in the lateral view: anterior, middle, and posterior.
      - The anterior column is composed of the anterior longitudinal ligament and the anterior two thirds of the vertebral bodies, the annulus fibrosus and the intervertebral disks.
      - The middle column is composed of the posterior longitudinal ligament and the posterior one third of the vertebral bodies, the annulus and intervertebral disks.
      - The posterior column contains all of the bony elements formed by the pedicles, transverse processes, articulating facets, laminae, and spinous processes.

        If one column is disrupted, other columns may provide sufficient stability to prevent spinal cord injury, however if 2 columns are disrupted, the spine may move as 2 separate units, increasing the likelihood of spinal cord injury.
    - Look at the overall alignment referring to the anterior vertebral, posterior vertebral, spinolaminar, and posterior spinous process lines.
    - Look for fracture lines following all the cortex of the individual bones.

LATERAL VIEW

True lateral view includes the top of the first thoracic vertebra (T1). If C1—the top of T1 cannot be visualized, then a swimmer's view should be attempted. If C1 to the top of T1 still cannot be visualized, then a CT scan must be completed.

- Know the anatomy of the c-spine (**FIGURE 71.1**).
- A lateral view must be obtained prior to removal of the collar if injury is suspected.
- Assess alignment of the anterior vertebral, posterior vertebral, spinolaminar, and posterior spinous process lines (**FIGURE 71.2**).
- Bony landmarks show the outline of each vertebral body. They should be rectangular and equal in size, with some variability (assess the body above and the body below; they should be comparable). Also assess the lateral mass, facet joint, lamina, facet, and spinous process (**FIGURE 71.3**).
- Cartilaginous space—Anterior atlantodental interval (AADI) "predental space." The distance from dens to body of C1. Measurement should not be more than 3 mm in adults and 5 mm in children. Increased space can signify odontoid fracture or transverse ligament injury (**FIGURE 71.4**).
  - Because of maternal duplication of chromosome 21 (trisomy 21) and the fact that chromosome 21 codes for Type VI Collagen, up to 10mm of space can be identified in this population.

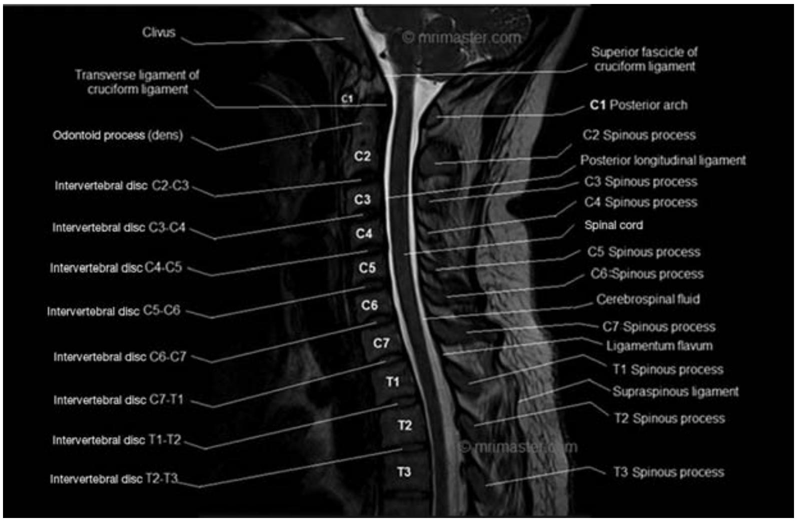

Clivus
Transverse ligament of cruciform ligament
Odontoid process (dens)
Intervertebral disc C2-C3
Intervertebral disc C3-C4
Intervertebral disc C4-C5
Intervertebral disc C5-C6
Intervertebral disc C6-C7
Intervertebral disc C7-T1
Intervertebral disc T1-T2
Intervertebral disc T2-T3
C1
C2
C3
C4
C5
C6
C7
T1
T2
T3
© mrimaster.com
Superior fascicle of cruciform ligament
C1 Posterior arch
C2 Spinous process
Posterior longitudinal ligament
C3 Spinous process
C4 Spinous process
Spinal cord
C5 Spinous process
C6 Spinous process
Cerebrospinal fluid
C7 Spinous process
Ligamentum flavum
T1 Spinous process
Supraspinous ligament
T2 Spinous process
©mrimaster.com
T3 Spinous process

FIGURE 71.1 Anatomy of the cervical spine seen via a lateral/sagittal view of an MRI.

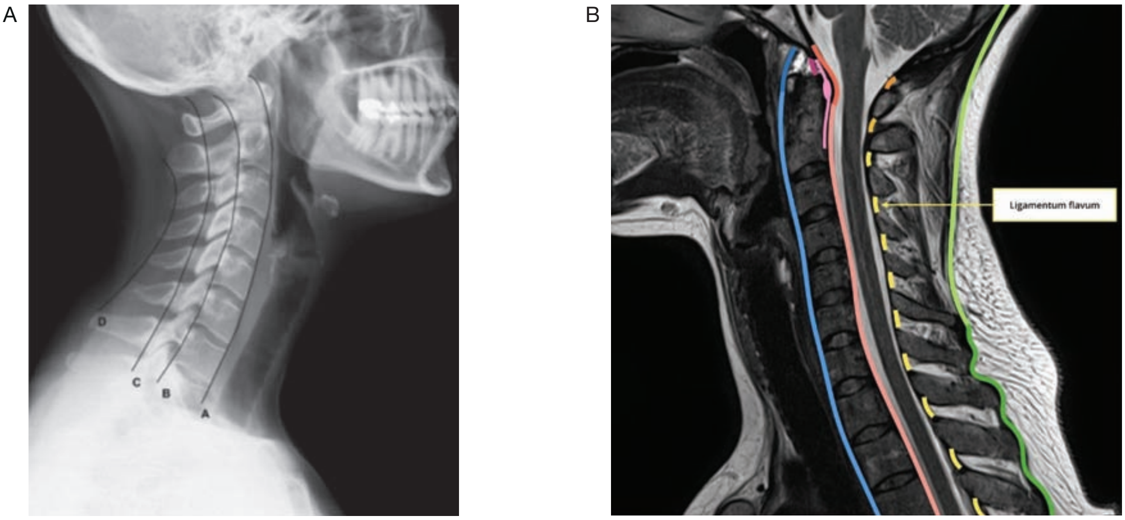

A
D
C
B
A
B
Ligamentum flavum

FIGURE 71.2 (A) Alignment. [A] anterior vertebral line; [B] posterior vertebral line; [C] spinolaminar line; [D] interspinous line. (B) Ligaments of the cervical spine.

Sources: (A) Campo, T. M. (2016). *Medical imaging for the health care provider: Practical radiograph interpretation*. New York, NY: Springer Publishing Company. (B) Frank Gaillard. (n.d.). Ligments of the cervical spine [Image file]. Retrieved from https://radiopaedia.org/cases/ligaments-of-the-cervical-spine-annotated-image?lang=us

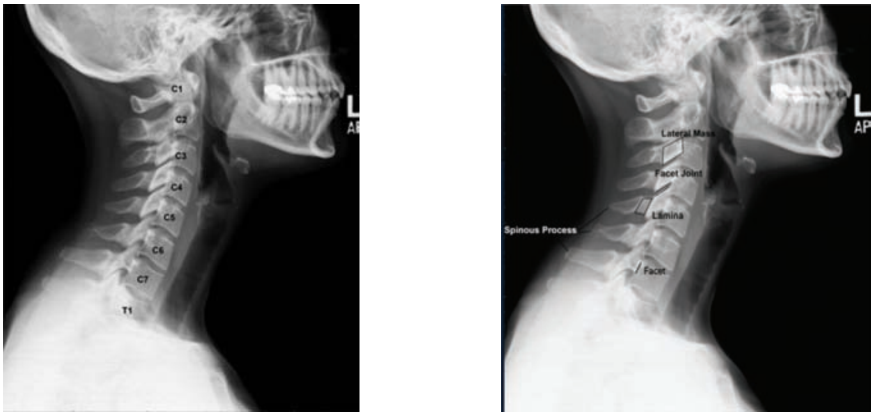
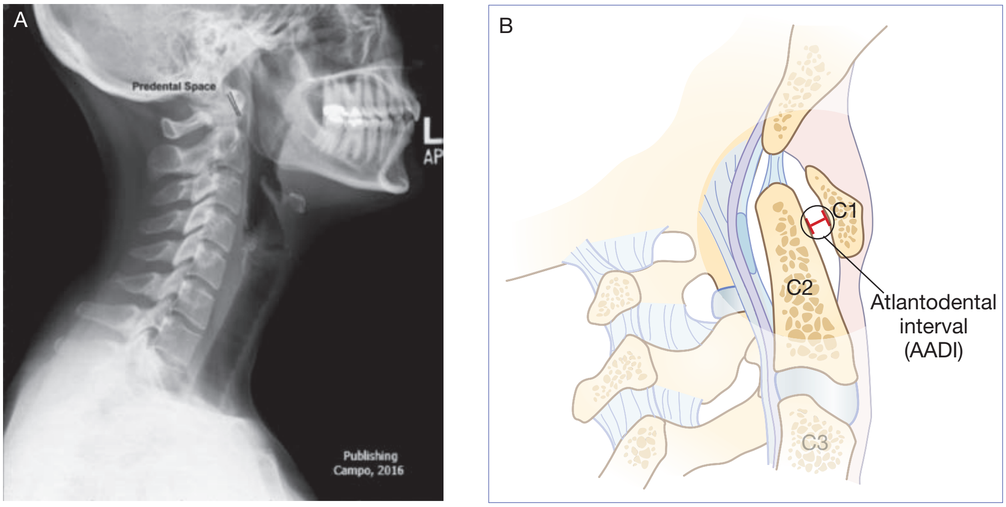

C1
C2
C3
C4
C5
C6
C7
T1
L
AP
Lateral Mass
Facet Joint
Lamina
Spinous Process
Facet
L
AP

FIGURE 71.3 Bony landmarks.

Source: Reproduced from Campo, T. M. (2016). *Medical imaging for the health care provider: Practical radiograph interpretation.* New York, NY: Springer Publishing Company.

FIGURE 71.4
(A) Cartilaginous space; (B) anterior atlantodental interval predental space.

Source: Reproduced from Campo, T. M. (2016). *Medical imaging for the health care provider: Practical radiograph interpretation*. New York, NY: Springer Publishing Company.


A
Predental Space
L
AP
Publishing
Campo, 2016
B
C1
C2
C3
Atlantodental interval (AADI)

- Disc space—Should be roughly equal and symmetrical anterior and posterior (**FIGURE 71.5**).
- Soft tissue—May indicate occult fracture (**FIGURE 71.6**).
  - Nasopharyngeal space C2–C4
    - Normally 5 to 7 mm in adults
  - Retropharyngeal space C5–C7
    - Normally 14 mm in adults
    - Normally 22 mm in children

AP VIEW (FIGURE 71.7)

- Alignment—Spinous processes (midline) and transverse process bilaterally
- Bony landmarks—Vertebral bodies

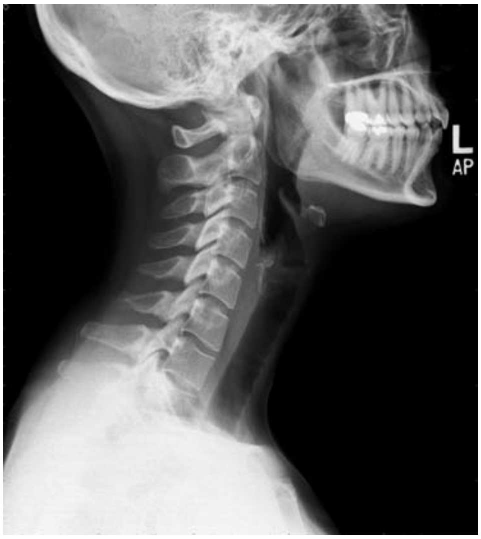


FIGURE 71.5 Disc space. Note that the space between each vertebra is equal anteriorly and posteriorly.

Source: Reproduced from Campo, T. M. (2016). *Medical imaging for the health care provider: Practical radiograph interpretation*. New York, NY: Springer Publishing Company.

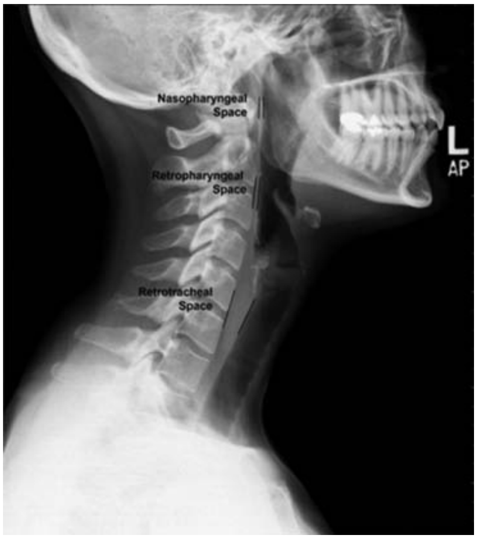

Nasopharyngeal Space
Retropharyngeal Space
Retrotracheal Space
L
AP

FIGURE 71.6 Soft tissue.

Source: Reproduced from Campo, T. M. (2016). *Medical imaging for the health care provider: Practical radiograph interpretation*. New York, NY: Springer Publishing Company.

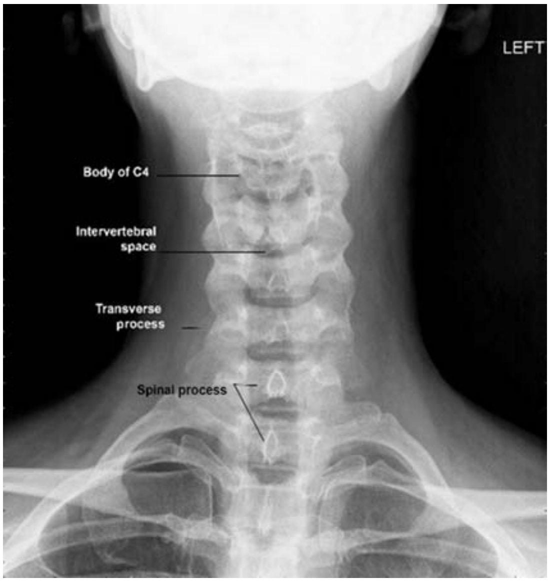

LEFT
Body of C4
Intervertebral space
Transverse process
Spinal process

FIGURE 71.7 Anterior–posterior view.

Source: Reproduced from Campo, T. M. (2016). *Medical imaging for the health care provider: Practical radiograph interpretation*. New York, NY: Springer Publishing Company.

ODONTOID VIEW

The odontoid view should visualize the odontoid process in its entirety (**FIGURE 71.8** and **FIGURE 71.9**). If there is any anatomic location that is obscured by teeth or surrounding structures, a repeat scan should be done.

- Vertebral body of C2
- Lateral masses C1
- As stated above, CT scan without contrast should be performed primarily as it is much more sensitive in evaluating injury to the spine. However, if not available and after plain X-rays are obtained and there is any of the following a CT scan or MRI must be carried out
  - significant injury
  - traumatic injury
  - abnormality is visualized on plain radiograph
  - no abnormality is identified on plain radiograph
  - and injury is suspected
- Note that the c-spine cannot be clinically cleared in patients with altered mental status or in the presence of a closed head injury, even if the radiographic images are normal.
- After determining there is no radiological abnormality, the c-spine must still be cleared clinically (see Clinical Clearance section).

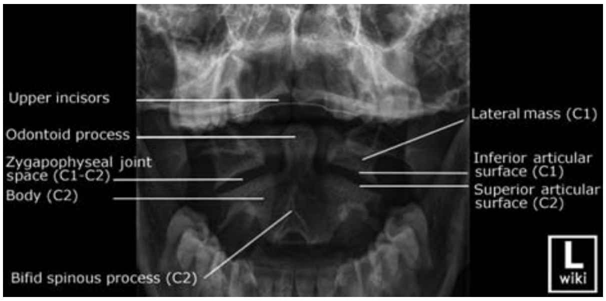

Upper incisors
Odontoid process
Zygapophyseal joint space (C1-C2)
Body (C2)
Bifid spinous process (C2)
Lateral mass (C1)
Inferior articular surface (C1)
Superior articular surface (C2)
L wiki

FIGURE 71.8 Odontoid view.

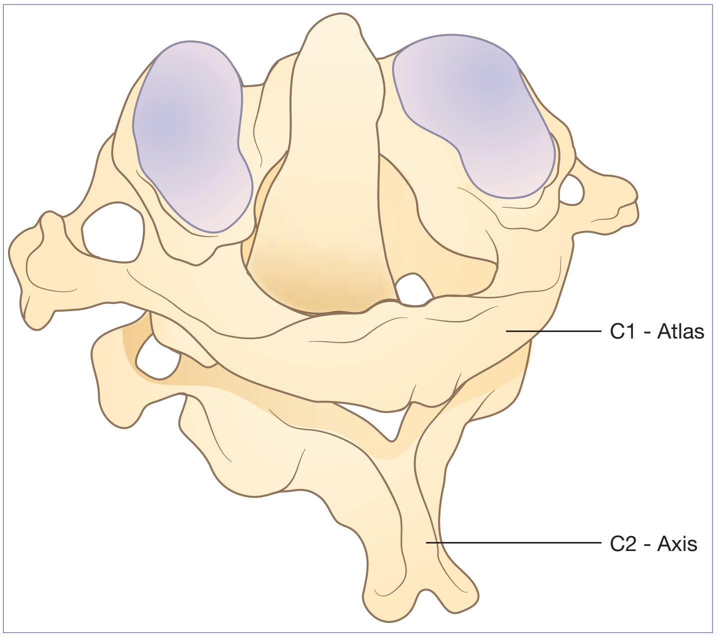

C1 - Atlas
C2 - Axis

FIGURE 71.9 Anatomical orientation of C1–C2.

POSTPROCEDURE CONSIDERATIONS

If an injury is suspected and/or there are clinical findings in the presence of medical imaging (radiograph, CT scan of c-spine) not demonstrating any abnormalities and the images have been read by at least two providers, an MRI should be considered.

EDUCATIONAL POINTS

- Age specific
  - Placing a pad under the baby's head can help to balance the larger head in comparison to the neck and body.
  - Padding can be used to protect the head and neck of the geriatric patient, especially if frail.
  - C-spine precautions can be maintained without a long board and cervical immobilization device (CID).

COMPLICATIONS

- Missed fracture or soft tissue injury (cartilage, ligament, etc.)
- Temporary or permanent neurological deficits
- Delay in diagnosis

PEARLS

- 5.4% of moderate to severe head injury patients have an associated cervical spine fracture; image the cervical spine in all of these patients.
- Plain x-rays have a sensitivity of 80% in diagnosing cervical fractures; use CT scans when able.
- Intoxicated and psychotic patients can mask cervical injuries with bizarre behavior; if a possible mechanism of injury exists, image their cervical spine.
- Obtaining information from not only the patient but the family member(s), witnesses, and ambulance and paramedic personnel as well as pictures obtained at the scene can be most beneficial when determining the extent of trauma and injury.
- Distinction of pain at the sternocleidomastoid muscles laterally versus c-spine pain is important.
- Note that the c-spine cannot be clinically cleared in patients with altered mental status or in the presence of a closed head injury, even if the radiographic images are normal.
- Electronic apps and checklists provide quick and easily accessible reminders of NEXUS and CCR criteria.

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